ECONOMIC GEOLOGY RESEARCH UNIT

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Johannesburg

A REVIEW OF THE PONGOLA SUPERGROUP AND ITS SETTING ON THE KAAPVAAL CRATON

by

B.F.WEILERS

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UNIVERSITY OF THE WITWATERSRAND

JOHANNESBURG

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ABSTRACT

This review is based on the work of many dedicated geologists who have contributed to our knowledge of the Pongola Supergroup, and the writer has freely used the information to compile this synthesis.

Rocks of Archaean age are exposed from Barberton southwards to the Natal thrust front, which marks the southeastern margin of the Kaapvaal Province. The entire area comprising the granitic basement, the Pongola Supergroup and the post-Pongola gabbro and granitoids exhibit a continuous record of crustal evolution spanning about one billion years from $\sim$ 3.5 to 2.6 Ga. Importantly, this is the only portion of the Kaapvaal Province where such a continuity of events can be chronicled in rocks that are so well-preserved.

Regional lithostratigraphic and sedimentological features of the Pongola Supergroup define three domains, referred to as the Northern, Central and Southern Domains. Structurally, however, the Pongola Supergroup occurs in two connected but contrasting domains extending across the southeastern region of the Kaapvaal Craton, within which the strata are exposed in several extensive but isolated areas within a belt about 100 km wide and extending southward from Swaziland to Northern Natal over a distance of some 270 km. The north-south trending northern domain has an asymmetric structure and disposition of the two principal stratigraphic units comprising the Pongola Supergroup, namely the lower predominantly volcanic Nsuze Group ($\pm$ 8 km thick) dipping eastward below the upper, mainly sedimentary Mozaan Group ($\pm$ 5 km thick). The Pongola sequence in the southern domain comprises essentially pure arenites with minor volcanic units and fine grained clastic sediments. The tectonic grain of the southern sector is dominantly east-west, and the estimated thickness of the Nsuze strata is approximately 5 kms. It has been postulated that the latter assemblage of strata was deposited in a subsiding epicratonic basin and represents the proximal segment of a miogeoclinal prism.

In the northern and central domains the overall nature of the clastic rocks at the base of the Nsuze group indicates deposition in a distal braided stream environment, whilst depositional models pertaining to the Mozaan Group indicate that sedimentation was dominated by two interacting environments, the braided alluvial plain and a tide-dominated marine basin.

The Pongola basin is explained in terms of a two stage thermo-tectonic model for the formation of aulacogens or syn-rift depositional basins. In terms of this model, the mainly volcanic Nsuze Group reflects the first-stage rift-forming event caused by uplift and crustal extension as a result of lithospheric heating. It is further postulated that the Mozaan basin reflects a response to the second stage or event of broad crustal downwarping induced by thermal cooling and contraction.

During subsequent uplift and erosion across the inland margin of the epicratonic basin, the Nsuze strata were downfaulted into northward dipping half-graben structures, which were truncated by erosion before the regional subsidence and expansion of the Mozaan depositional basin southwards to merge with the epicratonic basin and the continental margin. Northerly directed compressional tectonics resulted in a substantial thickness of strata becoming detached and transported northward as the Nsuze gravitational nappe, which forms a basal slide located at the Mozaan-Nsuze unconformity.

Recent age datings place the Pongola Supergroup at between 3028 Ma and 2871 Ma, an apparently distinct event of volcanism and sedimentation in a basin showing only quasi time equivalence to the Lower Witwatersrand sedimentation (dated at between 2980 Ma and 2914 Ma) and distinctly older than the Upper Witwatersrand sedimentation (dated at between 2840 Ma and 2714 Ma).

Gold mineralisation occurs in conglomerates within the Nsuze and Mozaan Groups and, more importantly, in shear zone hosted quartz-sulphide deposits in Mozaan sediments in proximity to post-Pongola granitoids of the Spekboom-type. It is considered unlikely that a significant gold deposit is associated with the conglomerate-hosted environments, whereas the structurally hosted vein deposits are regarded as the more viable targets for exploration.

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CONTENTS

	Page
PRE-PONGOLA BASEMENT	1
INTRODUCTION	1
STRATIGRAPHIC SUBDIVISIONS	1
THE PONGOLA SUPERGROUP	5
INTRODUCTION	5
BASIN FILL	5
Northern Domain	6
Amsterdam Area	6
Northern disrupted region of Pongola-Mozaan Basin	7
Mahlangatsha Belt	8
Kubuta Belt	8
Pongola-Mozaan Basin	10
Central Domain	24
Mpongoza Inlier	25
Wit Mfolozi Inlier	27
Southern Domain	30
STRUCTURE	34
BASIN GEOMETRY	40
GEOCHEMISTRY	42
GEOCHRONOLOGY	45
ECONOMIC ASPECTS	47
TECTONIC SETTING OF THE BASIN	55
"SYN"-POST-PONGOLA INTRUSIVES	56
ACKNOWLEDGEMENTS	60
REFERENCES	61

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PRE-PONGOLA BASEMENT

INTRODUCTION

Rocks of Archaean age ($\sim$ 2,6 Ga) are exposed from the Barberton area southward to the Natal Thrust Front. The latter marks the southeastern margin of the Kaapvaal province. Earlier studies in the eastern Transvaal and Swaziland have furnished data on a wide range of granitic rock types. These have been portrayed on many maps aimed at classifying the granitic rocks of the region (Anhaeusser et al., 1968; Hunter, 1957, 1970, 1973, 1979; Viljoen & Viljoen, 1969(a), (b); Visser et al., 1956; Wilson, 1982). To date, as a result of the complexity of this granitic terrain, there is no consensus on the correlation of these rocks, and widely different views have been expressed on the evolution of this primitive crust. The entire area including the Pongola Supergroup and post-Pongola gabbro and granites exhibit a continuous record of crustal evolution spanning about a billion years from $\sim$ 3,5 to 1,6 Ga; the latter age being close to the internationally recognised upper age limit of the Archaean at 2,5 Ga. This is the only portion of the Kaapvaal province where such a continuity of events lend themselves to be chronicled in rocks that are so well-preserved as a result of the heterogeneity of tectonic overprinting (Refer Maps 1 and 2).

A fundamental division of the essential stratigraphy is marked and defined by the widespread intrusion of granites at about 3,0 Ga, represented by the multiphase, tabular Lochiel (Mpuluzi) batholith. Emplacement of this prominent and extensive batholith enables a stratigraphic subdivision (Hunter and Wilson, 1988), into

(1) an Early Archaean, pre-Lochiel assemblage of granitoids in which are preserved remnants of metavolcanic/metasedimetnary supracrustal remnants of varying magnitudes, and

(2) Late Archaean rocks represented by the moderately deformed Pongola Sequence which is intruded by gabbro and granites.

The major stratigraphic subdivisions of (1) above are briefly discussed below.

EARLY ARCHAEAN

STRATIGRAPHIC SUBDIVISIONS (Refer Map 2)

(a) Ngwane Gneiss

This gneiss, also known as the Bimodal Suite or Ancient Gneiss Complex (Hunter, 1970), has fairly recently been dated at about 3,64 Ga (Kroner & Todt, 1988) and forms the sialic basement to the supracrustal assemblage forming the Barberton Sequence. It is estimated that only about 10% of the Ancient Gneiss Complex (AGC) retains this early age dating whilst some 90% of the rock unit was reset during a metamorphic event at about 3,2 Ga. This widespread unit comprises layered, grey tonalite gneisses with subordinate and apparently concordant thin amphibolites. According to Hunter (1970), the rocks bear a geochemical resemblance to acid and basic volcanics, and conceivably comprise part of a proto-continent sequence. The Ngwane Gneiss (AGC) displays a consistently high metamorphic grade, and has suffered the maximum number of deformations. Furthermore, the Ngwane gneiss amphibolites are geochemically distinct from those of other formations. Most convincing of all, the above data attesting to a proto-continent sequence is the fact that the rock unit is cut by suites of deformed mafic dykes, some of which because they are absent in the Onverwacht, are therefore likely to pre-date the Barberton Sequence.

(2) Barberton Sequence

Rocks of the Swaziland Supergroup crop out within the NW-trending Barberton greenstone belt. The belt consists of an assemblage of metamorphosed volcano-sedimentary rocks. These include mafic and ultramafic lavas (basaltic and peridotitic komatiite, high-Mg basalt and tholeiite), mafic to felsic volcanics and pyroclastics and sediments (greywackes, shale, banded iron formation, chert, quartzite and conglomerate). This rock assemblage comprises three major subdivisions, namely the Onverwacht Group at the base which is essentially a greenstone assemblage; this group is followed without a major break by the succeeding Fig-Tree Group in which flysch-type sedimentation is associated with ironstone; the Moodies Group lies unconformably on the Fig-Tree and Onverwacht outcrops. The geology of the Barberton Sequence has been described by Anhaeusser (1978), Viljoen and Viljoen (1969 (e)(d)) and Visser et al., (1956).

Some pertinent recent age datings are significant in adding some additional input into the nature of the early crust in the Barberton-Swaziland region. The following datings are therefore listed as of importance:

Onverwacht (Hooggenoeg Formation)	3,45 Ga
Felsic volcanics from Fig-Tree	3,26 Ga
Ignimbrite at base of Moodies	3,23 Ga

These datings would support the contention by Hunter (1974a), and Hunter et al., (1978) that the Bimodal Suite (3,64 Ga) predates the Onverwacht Group greenstones and may therefore represent the basement to the latter as outlined earlier in this text.

(3) Other Archaean Supracrustal Sequences (See Maps 1 and 2)

Five geographically and lithologically distinct sequences have been recognised in the area extending from approximately 100 km south of the Barberton sequence to the Natal Thrust Front. These are briefly described as follows based on the continuing investigations by the Archaean research group at the University of Natal, Pietermaritzburg (Hunter and Wilson, 1988; Versveld, 1988; Sleigh, 1988; Smith, 1987).

The Dwalile Metamorphic suite:

This suite comprises a number of scattered remnants which have been metamorphosed to lower amphibolite facies and infolded with bimodal gneisses of the Ancient Gneiss Complex. The suite is lithologically similar to parts of the Onverwacht Group at Barberton, is typically preserved in the cores of synclines and seems to be younger than the bimodal gneisses.

Brereton Park - Assegaai Supracrustal Suite

The Assegaai Supracrustal Suite crops out as a belt 100 km² in extent and elongated north-northeastwards. It has a maximum length of 25 km and a maximum width of 5 km. The southwestern part of the belt is split by a leucotonalite intrusion. The Assegaai suite is characterised by the presence of clastic and chemical sediments. Coarse grained metasediments consist of thin ferruginous quartzites. Metapelites where present include quartz-sericite, quartz-chlorite, quartz-fuchsite and quartz-biotite-muscovite schist. Prominent areas of banded-ironstone are exposed over fairly large areas.

Ultramafic and mafic schists exhibit strong foliation, but occasionally deformed pillows are preserved. The tholeiitic metavolcanic rocks now comprise an assemblage of amphibole, plagioclase and minor quartz. The ultramafic schists consist of combinations of chlorite, tremolite, actinolite, talc and serpentine. Minor calc-silicate rocks are present in small outcrops.

The relatively small de Kraalen remnant has predominant lithologies consisting of banded iron-formation and metaquartzite with lesser amounts of silicified calc-silicate rock and amphibolite.

Commondale Supracrustal Suite: comprises a dominant pile of mafic and ultramafic rock with only minor metasedimentary and calc-silicate interlayers. The Commondale suite is preserved in two synformal keels. A rhythmically alternating sequence of spinifex-textured cumulate layers is preserved in an area of low strain, whereas in areas of high strain the ultramafic rocks are serpentinized and retrogressed to talc-chlorite schists.

The dating of the Commondale and Assegaai greenstones has been placed tentatively as ranging from 3337 $\pm$ 13 Ma and 3268 $\pm$ 38 Ma by the Sm/Nd whole rock and the Rb/Sr technique respectively for the Matshempondo Peridotite which is spatially associated with the Commondale greenstones and for intrusive granites to the west of Piet Retief. (Personal communication D.R. Hunter).

Supracrustal inclusions in granitoid rocks: Amphibolite is the most abundant rock-type in these remnants. Layered amphibolites are also present and are distinguished by the presence of dark-coloured, coarse-grained, metaquartzite boudins.

Nondweni Supracrustal Suite: These supracrustal rocks crop out sporadically over an area of about 200 km^2 from beneath a thin Karoo cover. The Nondweni sequence is subdivided into a lower Mogongolozi Formation and an upper Witkop Formation. They consist of mafic and ultramafic igneous rocks with minor intercalations of acid lavas and pyroclastics and sedimentary rocks. The dominant lithologies are pillowed basalts interlayered with komatiitic basalts.

Subvolcanic inclusions and intrusive gabbroic bodies accompany the volcanic sequence.

Rhyolites and felsic tuffs are common in the northernmost outcrop of the remnant and represent the lowest, preserved stratigraphic unit of the Witkop Formation.

Early Archaean Granitoids: Hornblende tonalites and leucocratic trondhjemites underlie large areas of the Archaean granitic terrain in both the Eastern Transvaal and Swaziland. These rock types are collectively considered as constituting some of the oldest cycles of granitic activity. The tonalites and trondjhemites generally form discrete bodies which are invariably gneissic. The best exposed and most extensively developed tonalites and trondhjemitic gneisses in the Eastern Transvaal occur immediately south of the Barberton greenstone belt. Robb and Anhaeusser (1983) have identified no less than 13 bodies of tonalite and/or trondhjemite, each of which has been delineated and mapped. The gneisses are homogeneous and display a foliation which parallels the greenstone-gneiss contact.

The Mahamba Gneiss is present in several areas in Southern Swaziland. The highly metamorphosed semi-pelitic garnetiferous gneisses were at one time equated with the Ngwane Gneiss, but it is now considered that they may be considerably younger.

It should be noted that the hornblende tonalites referred to above have equivalents in Swaziland and have been referred to as the Tsawela and Mhlatuzane gneisses. Further intrusions into the Ngwane Gneiss is evidenced by the sheet-like Mponono Anorthosite Suite.

The above period of granitoid intrusions was followed by a major deformation event which affected both the greenstone belt and the other rocks. Roering (1967) states that structural investigations show that the main period of deformation in the Barberton Sequence is closely related to the metamorphism of the granite contacts. He therefore concludes that folding was essentially synchronous with the metamorphism initiated by an energy source from the intruding granites, the bulk of all varieties of which may possibly have been emplaced more-or-less simultaneously. After the climax of deformation had passed, the post-greenstone intrusive phase continued with the emplacement (broadly parallel to the greenstone belt) of the composite Usutu Intrusive Suite. Some acidic members of this suite contain hypersthene and others, milky blue opalescent quartz suggesting high grade charnockitic affinities.

The Lochiel (Mpuluzi) Granite is a major batholith which was intruded in a number of pulses to form a sheet-like carapace or hood over the subjacent gneisses. Whereas the earlier magmatic cycle is characterised by Na-rich tonalites and trondhjemites, the Lochiel Granite involves more K-rich magmas. These Na-rich and K-rich granitoids represent the First and Second magmatic cycles proposed for the Archaean crust of this area by Anhaeusser and Robb (1981) respectively. It was the emplacement of this batholithic body which essentially cratonised the previously mobile eastern part of the Kaapvaal area, and established a gravitationally stable zone at least 35 km thick. Moreover, the intrusion of the Lochiel batholith resulted in the emergence of a large, elevated continental fragment. Following the intrusion of the multiphase and extensive Lochiel batholith, the Pongola Sequence was deposited in a basin developed on its southeastern flank. It is considered that initial cratonization was completed at about 3,0 Ga.

Although the identification of depositional environments in some of the greenstone sequences remains equivocal, there is clear evidence that the provenance of the upper sedimentary groups of the Barberton sequence (i.e. the Fig Tree and Moodies) lay to the south. However, following intrusion of the Lochiel batholith, reversal of transport direction occurred with sediment being transported into the Pongola basin from the north and northwest.

Consideration, however, should also be given to the presence of a Basement arch located between Amsterdam and Piet Retief. This arch involves rocks of the Ancient Gneiss Complex and could conceivably have constituted a prominent high standing feature. This arch may therefore have profoundly influenced the northward directed sediment with regard to the Fig Tree and Moodies Groups. This is partly supported by the work of van Vuuren (1965) which indicated a north to northwesterly transport direction in a Mozaan bed within the Amsterdam synclinal trough.

THE PONGOLA SUPERGROUP

INTRODUCTION

The early Precambrian Pongola Supergroup in eastern South Africa consists of the lower, predominantly volcanic Nsuze Group overlain by the Mozaan Group which is composed mainly of sedimentary rocks. A palaeosaprolite is developed on the underlying Archaean granitoid basement. (Matthews and Scharrer, 1968).

The Nsuze Group comprises a basal sedimentary-volcanic unit overlain by a thick sequence of basalts, basaltic andesites, andesites, dacites and rhyolites which attain a maximum thickness of 8500 m. Minor volcaniclastic and sedimentary rocks are intercalated with the lavas. The transition to the overlying Mozaan group consists of interfingering sedimentary and volcaniclastic rock assemblages. The Mozaan Group contains fluvial, shallow marine, deltaic and/or shelf sediments with minor volcanic intercalations (Watchorn, 1978), and attains a thickness up to 5 000 metres.

The Pongola strata have been assigned Supergroup status by von Brunn (1974), von Brunn and Hobday (1976), von Brunn and Mason (1977) and Watchorn (1978).

The northern occurrences of volcanic rocks of the Pongola Supergroup were originally known as the Lower Pongola Series (Humphrey and Krige, 1931 (a), (b)) and the southern outcrops were referred to as the Insuzi Series (du Toit, 1931). Truter (1950) extended the use of the term Insuzi Series to include all the volcanic rocks of the Pongola Supergroup in northern Natal and south-eastern Transvaal and also applied the name Mozaan Series to the upper, predominantly sedimentary unit of the Pongola Supergroup. The names Insuzi and Mozaan have since been extended to include strata occurring in southwestern Swaziland. The spelling of Insuzi has since been changed to Nsuze.

BASIN FILL

Regional structural features of the Pongola Supergroup, as well as lithostratigraphic and sedimentological characteristics, define three extensive and essentially contrasting domains. These are referred to as the northern, central and southern domains, within which the strata of the Pongola Supergroup are exposed in several extensive but isolated areas within a belt about 100 km wide and extending southward from southern Swaziland to Northern Natal, a distance of some 270 km.

Northern Domain

Within this domain the Pongola Sequence rocks are apparently preserved in several mainly synclinal structures in the Amsterdam area; the northern disrupted region of the Pongola-Mozaan basin; as well as a thick succession in the Pongola-Mozaan basin referred to as the Hartland basin, and the Piensrand-Maguda basins within which the Mozaan strata have been preserved and deformed into an interlocking mozaic of perisynclines 10 km across, that are separated either by narrow perianticlines or by major faults. The Piensrand-Maguda basin, if it could be considered as a single entity, was disrupted by the intrusive Spekboom granite.

Amsterdam Area

Mapping by van Vuuren (1965) in the eastern Transvaal has shown the Pongola Supergroup partially preserved in an synclinal trough (situated to the northwest of the main basin), the axial portion of which is largely occupied by strata of the younger Karoo cover. The Nsuze and Mozaan group of lavas and sediments are clearly dismembered and enveloped by basic intrusives of the Usushwana Complex.

Hammerbeck (1982) has classified type areas in accordance with the lithostratigraphic nomenclature (SACS 1980) based on his mapping north of latitude 27°S, as well as the work done by van Vuuren (1965) and Visser et al. (1947). Details of this classification for the Amsterdam area are shown on Fig. 1.

The Nsuze Group

The basal Nsuze or Mantonga Quartzite Formation rests with a sedimentary contact on the Basement (Lochiel) granite. The thickness of the quartzite is of the order of 200 to 250 metres. Characteristic of the upper portion of the quartzite is its finely bedded nature. In the southwestern limits of the syncline a thin 30 metre layer of basaltic lava is intermittently present. The basal unconformity is frequently conglomeratic with pebbles averaging some 1,5 cms in diameter. Mapping by van Vuuren has shown the conglomerate to grade along strike into a coarse-grained to gritty quartzite, and cross-bedding has only been noted in this basal unit.

The Mantonga Formation is overlain by a thick pile of mafic lava some 2 000 metres thick with intercalated zones of amygdaloidal lava. This thick zone of lava comprises the Bivane Formation and is clearly equivalent to the Bivane Formation in the area south of Piet Retief (Fig. 1). The overall composition of the Bivane lavas corresponds quite closely to that of andesibasalt, suggesting the lava is intermediate between andesite and tholeiite or basalt.

The Mozaan Group

In the Amsterdam area, the Mozaan Group forms a northwest-southeast trending closed synclinal trough. The Group consists of two prominent quartzite members separated by an extensively outcropping ferruginous shale band with a maximum thickness of some 30 metres. The name Skurwerant Quartzite Formation has been adopted for the latter succession with a total thickness of some 390 metres (see Fig. 1). The persistent ferruginous shale band is known as the Madola Shale member (Krige and Humphrey, 1931).

The Skurwerant succession is overlain by a succession of quartzite (180 m thick), followed by a thick succession of ferruginous shale with an intercalated bed consisting of banded iron-formation some 13 metres thick. This succession of quartzite and shale forms the Redcliff Formation, and the iron-formation is referred to as the Cascade member. The total thickness of the Redcliff Formation is about 2 000 metres, composed almost exclusively of shale with 16 intercalated thin quartzite beds (van Vuuren, 1965), varying in thickness from 0,6 m to 9 m.

According to van Vuuren the quartzitic beds are mainly medium to coarse-grained with intercalated lenses of grit and conglomerate. A comparison between the sediments of the Nsuze Group and the quartzitic members of the Mozaan Group show the following differences:

- Light green coloured quartzites are more common in the Nsuze Formation
- Cross-bedding is well-developed in the Mozaan Formation, but occurs only occasionally in the Nsuze
- The quartzitic members of the Mozaan Formation are distinctly coarser-grained than those of the Nsuze
- the Nsuze sediments are finely-bedded as compared to the more massive nature of the quartzitic zones of the Mozaan Group.

Within the quartzitic zone of the Mozaan Group there is a distinct decrease in the number of conglomerate bands from the northwestern to the southeastern limb of the Amsterdam syncline. There appears to be an upward-coarsening sequence in the grain size of the quartzites.

The pebbles constituting the conglomerates are generally poorly rounded and consist essentially of white and smoky quartz and rarely of felspar. Sago texture is quite common in the quartzitic zones of the Mozaan.

Cross-bedding is well-developed in the Mozaan quartzites. Some 60 measurements from a specific bed indicate a north to northwesterly transport direction of the sediments. Cross-bedding above this specific quartzitic bed, however, indicates other transport directions. No statistical sets of measurements for the entire area was ever attempted, and the results therefore remain equivocal.

van Vuuren describes the Redcliff Formation as comprising essentially shale and sandy shale with numerous thin quartzite and banded ironstone layers. In general, the shale is ferruginous and weathers to a reddish brown colour. The shale alternates with thin layers of dark grey and black manganiferous types and occasional pink sandy intercalations. The basal portion of the shale member consists of a fine-grained light yellow to light red flagstone.

The Cascade member banded ironstone consists of alternating thin layers of red to reddish-brown glistening shale and white to light grey chert. Grey massive hematite and magnetite lenses and banded red jaspers are sporadically present. In proximity to faults the banded ironstone loses its typical banding and is transformed into a dark-grey to black massive manganiferous rock type.

The significance of the banded iron formation in the Amsterdam syncline, with regard to the depositional environment will be discussed elsewhere in the text.

Northern Disrupted Region of the Pongola-Mozaan Basin

Sizeable remnants of this portion of the basin occur as two narrow belts of Pongola Supergroup strata ranging in outcrop width from 3 to 12 kms trending north-northeast across southern Swaziland. These belts are prolongations of the main southern coherent part of the structure situated to the southeast and east of Piet Retief and Paul Pietersburg respectively, and known as the Pongola-Mozaan basin. In Swaziland and the SE Transvaal the emplacement of the Usushwana Complex has dismembered the basal units of the Nsuze Group.

The two northerly trending belts of Pongola strata are some 30 km apart and are known as the Western or Mahlangatsha belt and the eastern or Kubuta belt respectively. The belts are separated by extensive intrusive granites comprising the Hlatikulu pluton and the Nhlangano gneiss dome (Map 1).

Mapping in these areas was completed and revised over a protracted period by Gordon Hamilton in 1938; Hunter in 1952 and 1953; Mehliss 1961 and Winter 1962.

Mahlangatsha Belt

Nsuze Group

This predominantly volcanic succession shows the more extensive development in the Mahlangatsha area. The volcanics are essentially andesites with a fine-grained texture. Amygdales are occasionally developed and may reach up to 0,13 cms in diameter. They contain calcite, quartz and minor epidote, zoisite and chlorite. The andesites are overlain by acid volcanics which extend eastwards beneath the overlapping Mozaan quartzites. These acid volcanics are dark, very fine-grained rocks with a bluish-black colour, and may be amygdaloidal. No development of tuffs and agglomerates are known to be present.

The andesites are considerably altered and their original composition is often uncertain. The plagioclase exhibits extensive saussuritization, but the little that remains appears to have the composition of oligoclase and andesine.

Sedimentary intercalations are very rare except for a phyllite which overlies the acid volcanics, and attains a maximum thickness of some 90 metres before thinning and dipping beneath the overlap by the Mozaan Group. These phyllites are uniformly fine-grained and show evidence of metamorphism, with pyrophyllite, sericite, choloritoid and minor andalusite sporadically noted.

The Nsuze group in this belt of exposures thins out northwards and terminates near the Ingwempisi river. The recognition of the basal contact coupled with the overstep of the Mozaan serves to restrict the thickness of the Nsuze within the Mahlangatsha belt to a maximum of some 350 metres, as compared to some 6050 metres in the Pongola-Mozaan basin situated to the south.

Mozaan Group

In the Mahlangatsha belt the Mozaan comprises quartzites and conglomerates with minor shale intercalations overlying the Nsuze group. These rocks are a northward continuation of the type area south and southeast of Piet Retief.

Hunter (1953) and Winter (1962) have established the following stratigraphic succession based on their mapping of the area. The stratigraphy is summarized by Hunter (1963) as a result of additional mapping. The succession comprises an alternating sequence of seven quartzite beds with six intercalated shale bands. The quartzite beds thicken upwards from some 9 metres at the base of the succession to about 305 metres at top (7th quartzite) bed. In all, the seven quartzitic members total a maximum of 870 metres. Conglomerate bands are present in all of the quartzite beds and are located mainly at the base of these beds. The six shale bed intercalations have a total thickness of 250 metres and comprise pale sandy shales, purple shales, phyllites and development of ferruginous shales with magnetite and haematite in the six shale members at the top of the succession immediately below the 7th quartzite member. The succession briefly described here, compares closely with that established by Humphrey and Krige (1931) in the Piet Retief district. Thus, the ferruginous shale between the fourteenth and fifteenth quartzites of Humphrey and Krige correlates with the six shales in the Mahlangatsha area.

Kubuta Belt

Nsuze Group

The occurrence of Nsuze volcanics east of Kubuta contains highly altered lavas with lenses of metaquartzites and, occasionally, phyllite. The lavas are variable and are either dark, medium or fine grained textured or pale, olive-green types with a similar variation in grain size. These latter types are occasionally amygdaloidal. In proximity to intrusive granitoid contacts the lavas coarsen in grain size and reflect a high grade of metamorphism, with development of massive, coarse-grained chiastolite-bearing gneissic, and pale yellow-brown fissile schists.

The lavas are generally considerably altered and consist of amphibolite, quartz and felspar. The amphibole varies from hornblende to a paler green tremolite. The felspars are extensively saussuritized but appear to have been andesine. Carbonate has been observed sparingly developed in the amygdales which also contain chlorite and zoisite.

The associated sedimentary horizons within the lava sequence are lenticular in shape with their longer axis parallel to the general strike. Mapping has indicated fou major lenses of quartzite with minor intercalations of phyllite which, although separated along strike, appear to comprise the same stratigraphic horizon. The metamorphosed parts of these rocks contain much chiastolite, which occurs as large turbid insets with serecitised inclusions.

The structure of the Nsuze volcanics in the Kubuta area is difficult to determine. The overall dip appears to be to the east at between 50 and 60 degrees. The lack of marker horizons obscures the degree of faulting that could have been present, but at the north end of the outcrop faulting is extensive. The thickness of the succession is therefore unknown, and in any event, the rocks are overlain by the Karoo System.

Mozaan Group

The Mozaan succession in the Kubuta belt differs from the Mahlangatsha area in that argillaceous horizons are of considerably greater importance. The basal quartzite of the Kubuta area is correlated with the seventh quartzite (i.e. the topmost) quartzite at Mahlangatsha. This quartzite forms the base of the succession in the Kubuta area and is the only arenaceous horizon which reaches considerable thickness, of about 490 metres. This basal quartzite shows no clearly displayed relationship with the gneisses on which it rests, but there is no doubt that it has a sedimentary contact with those gneisses which strike nearly at right angles to the seventh quartzite. The basal or seventh quartzite is followed in upward succession by eight shale horizons with seven intercalated quartzite beds containing intermittent accompanying bands of small pebble conglomerate.

The shale successions are essentially ferruginous with development of ironstones, sandy partings and occasional jaspers. The quartzite beds are mostly light-coloured and often cross-bedded. At the top of the Mozaan succession, overlying the 14th shale bed are some 152 metres of dark amygdaloidal basaltic lavas.

In all, the total maximum thickness of the Mozaan Group near Kubuta is some 3078 metres, comprising 1082 metres of quartzite in 8 beds (7th to 14th quartzite units), 1844 metres of intercalated shales in 8 beds (7th to 14th shale units) and a capping of 152 metres of amygdaloidal lavas. As a result of his observations, Hunter (1963) concluded that the Kubuta sequence stratigraphically overlies that of the Mahlangatsha area as described above, and that the Mozaan sediments had a northern provenance area. This latter conclusion is not well substantiated but is based on the observation that when the mozaan Group is traced northwards from the Mahlangatsha belt to the Ngwempisi River, the sediments gradually become coarser in grain suggesting that the source of these sediments entered the depository from the north.

The presence of ripple marks and conglomerates is considered by Hunter (1963) to suggest that the Mozaan Group was deposited in shallow water and close to the shoreline. Furthermore, it is significant to note that the absence of the lower Mozaan succession at Kubuta is evidence of a transgression towards the east. The pebbles of the conglomerate bands throughout the Mozaan in these belts are not sufficiently diagnostic to identify the source rocks, in as much as the pebbles are mostly vein quartz.

PONGOLA MOZAAN BASIN (Districts of Piet Refief and Vryheid)

The Pongola Supergroup is best developed in this area. The Nsuze Group has the best exposures in the area north and south of the Pongola River where it attains a maximum thickness of about 8000 metres, and is conformably overlain by sediments of the Mozaan Group.

Nsuze Group

The earliest mapping of the Nsuze volcanics and sediments in the country south of Piet Retief was by Krige (Humphrey and Krige, 1931). However, the first lithostratigraphic study and sedimentological analysis of the Nsuze Group in this basin was made by Armstrong (1980); Watchorn and Armstrong (1980); and Armstrong, Hunter and Wilson (1982). Further studies relating to the geochemistry of the Nsuze as indicators of the tectonic setting was presented by Armstrong, Wilson and Hunter (1986) and will be referred to elsewhere.

The basal Nsuze Group rests on the underlying basement with a graded unconformity where a quartz-serecite palaeosaprolite is developed (Mathews and Scharrer, 1968). This palaeosaprolite is occasionally exposed in stream sections, and consists of a structureless, hard, medium to coarse-grained, cohesive rock which grades into the underlying granite. The saprolite varies in thickness from 2 to 10 metres. The contact with the overlying sediment of the Nsuze Group is not easily recognised and was seldom observed. Mathews and Scharrer (1968) noted that the top of the paleosaprolite is marked by crude bedding exhibiting increase in quartz and decrease in argillaceous material. It seems reasonably clear that this zone of indurated quartz-serecite-vermiculite rock was derived in situ from the underlying granite. It is reasonable to assume that the saprolite was a major source of material for the quartz wackes in the immediately overlying lower Nsuze sedimentary rocks.

Within the type locality in the vicinity of the Bivane and Pongola Rivers, the Nsuze Group can be sub-divided as follows:

1. a lower sedimentary-volcanic unit comprising the Wagendrift (± 300 m) and Mantonga Formations (± 800 m thick);

2. a middle, volcanic unit with minor intercalated volcaniclastic and sedimentary rocks of the Bivane Formation (± 7 500 m thick), and

3. an upper volcaniclastic-sedimentary unit of the Roodewal Formation (5 to 600 m thick).

1. The lower sedimentary-volcanic units of the Nsuze Group comprising the Wagendrift (± 300 m thick) and the Mantonga Formation (± 800 m thick), have been described in some detail by Watchorn and Armstrong (1980) with additional supplementary information by Armstrong, Hunter and Wilson (1982). The lower sedimentary unit of the Nsuze in the Pongola-Mozaan basin is best exposed over a 15 km strike

length situated north of the Pongola River. In most of the other localities, the outcrop continuity is masked by cover of Karoo rocks or is dismembered by the widespread intrusion of rocks related to the Usushwana Complex.

Wagendrift Formation: Consists of basic volcanics apparently deformed prior to the main period of Nsuze Group sedimentation and volcanism. Sandstones, less than 30 metres thick, are intermittently developed at the base of the approximately 300 m of these basaltic volcanic rocks. Poor outcrops of the sediments precludes detailed sedimentological observations, whilst the lack of identifiable primary structures in these lavas, their structural relationship to the main occurrence of Nsuze Group rocks, and the underlying basement, is obscure. It seems most likely, however, on the basis of chemical and mineralogical similarities to the Nsuze Group lavas, that these basal volcanics apparently reflect an early depositional phase of the Nsuze Group.

Mantonga Formation: This formation was earlier referred to by Armstrong (1980) as the Warmbad Sub-unit. The Formation consists of an 800 m-thick sequence of intercalated sandstones, lavas and volcaniclastic rocks resting on a granitic palaeosaprolite. The predominant rock-types in the Mantonga Formation are immature, medium to coarse-grained quartz wackes intercalated with thin (5 to 30 m) lenses of quartz and arkosic arenites. The quartz wackes are either structureless or show planar and trough cross-stratification. The interbedded quartz arenites are clean, mature sandstones with very minor fine-grained matrices. Conglomerates (maximum thickness 50 cm), are best developed in the lower 100 m of this Formation, and were deposited as lags within a hydrodynamically fluctuating system. Most of the conglomerates are matrix-supported within which clast supported phases are present. Subrounded to sub-angular vein quartz and chert are also present. The matrix of the conglomerates is very coarse to gritty quartz wacke, suggesting rapid deposition and little or nor reworking. No significant thicknesses of argillaceous sedimentary rocks are present. The only mudstones observed are in the form of drapes associated with ripple cross-laminated sandstones.

1.1 Sedimentology

Sedimentary structures are mostly poorly preserved in the basal Nsuze Group. This lack of structure has been attributed to inherent instability of the wackes as well as the growth of new minerals during low grade metamorphism. The basal sandstones comprise a thick tabular unit, thickening slightly towards the north. These sandstones are mostly immature and medium to very coarse-grained with thin intercalated grits and conglomerates. Conglomerates occasionally overlie an irregular erosion surface at the base of a 1-2 m upward-fining cycle. These features, and the prevalence of unimodal palaeocurrents, and the underlying paleosoil points to deposition in a fluvial regime, probably braided as suggested by the absence of fine-grained clastics.

Trough cross-beds are the dominant sedimentary structures. They generally occur as superimposed sets, with an average set thickness of 20 cm. Solitary sets of planar cross-stratification are intercalated within trough cross-bedded units. The sets are up to 40 cm thick and display an angular attitude to the underlying strata. In braided streams, planar foresets are generally indicative of transverse bars. Palaeocurrent rose diagrams and calculated vector means indicate a palaeoflow direction varying between northeast to southeast, suggesting the fluvial system drained an undulating terrain.

Thick sequences of plane beds frequently locate stratigraphically above trough cross-bedded units. The sandstones which contain these structures are often finer-grained than the cross-bedded members and are devoid of any pebbles.

Current ripples are confined to the medium-grained sandstones, and both straight and sinuous crested varieties are present. According to Armstrong (1980) these bedforms have been recognised and described in the literature as forming in ephemeral streams, where the sinuous crests develop within channels and the linear ripples are restricted to the tops of cross-channel bars. It is probable therefore that these structures formed on bars during falling water stages, and would support the fact that current ripples in the Nsuze Group are poor indicators of flow direction because during falling water stages, the flow is diverted by the emergence of bars.

Mention should be made that maroon-coloured, ferruginous sandstone beds are irregularly developed within the sedimentary sequences.

1.2 The Intercalated Volcanic and Volcaniclastic Rocks

The rocks of volcanic origin intercalated with the arenaceous sediments in the Mantonga Formation include both flow and fragmental types. The flows are mainly confined to the northern part of the area studied by Armstrong (1980). Volcaniclastics comprise both pyroclastic rocks and volcanogenic sediments. The latter consists essentially of reworked pyroclastic deposits mixed with sedimentary material. Significantly the influence of volcanic activity decreases towards the south, since no evidence of volcanogenic deposits are found in the southernmost exposures of the Mantonga Formation. The southern pyroclastic accumulations are finely tuffaceous in character and suggest deposition considerably distal from the source.

The lava flows range in composition from basaltic andesite through andesite and dacite to rhyolite. The classification is based on their metamorphic minerals combined with chemical criteria (Armstrong, Wilson and Hunter, 1986). The flows are generally laterally impersistent and vary from 2 to 30 m in thickness. Textural types such as amygdaloidal, vesicular and porphyritic are common in the basic and intermediate lavas. The rhyolitic flows are characterised by spherulitic textures.

The pyroclastic rocks are abundantly represented by air-fall tuffs, but include minor agglomeratic phases and a welded ash-flow unit. The air-fall tuffs are compacted rocks both fine and coarse-grained and locally well stratified. These tuffaceous horizons are up to 120 m thick containing agglomeratic zones, intercalated lava flows and sediments.

Agglomerates occur in localised zones, up to 40 m in extent, and sporadically developed within the tuffaceous units. Their texture suggests ejection during explosive eruption. Variations in clastic composition and texture points to a derivation from a diverse source.

An acid volcanic unit shows features indicative of a welded ash-flow origin. Crystals orientated perpendicular to bedding, and lithic and pumice fragments which show signs of welding and compaction are useful criteria to distinguish the welded tuffs from normal lava flows.

1.3 Volcanogenic Sedimentary Rocks

Two types of volcanogenic sediments have been identified within the Mantonga Formation, namely a coarse lithic wacke derived from semi-consolidated pyroclastic accumulations identified by coherent fragments of tuffaceous material in a matrix of sedimentary origin and secondly, wackes formed either by the contribution of pyroclastic directly from the air into the sub-aqueous environment, or by reworking of unconsolidated tuffaceous deposits.

1.4 Sedimentary-Volcanic Interrelationship

The spatial relationship between the fluvial sandstones and intercalated lenses of extrusive rocks suggests contemporaneous sedimentary deposition and volcanic activity as evidenced by the presence of occasional pyroclastic bombs and lapilli explosively ejected into the adjacent clastics. Discrete, elongated lenses of amorphous chert, up to 15 cm in length were recorded over a 3 m stratigraphic thickness within the sediments. The lenses are concordant with the bedding and it has been suggested that they represent colloidal precipitates related to proximal volcanicity.

Contact relationships between sedimentary beds and lava flows are generally sharp, with the fluvial sediments erosional into the underlying volcanics. Contacts between the lavas and the sediments, show the lava to be chilled and slightly autobrecciated. The contact relationship between volcaniclastics and the fluvial sediments is predominantly gradational. Volcanogenic sediments are confined to the transitional phases (Fig. 2).

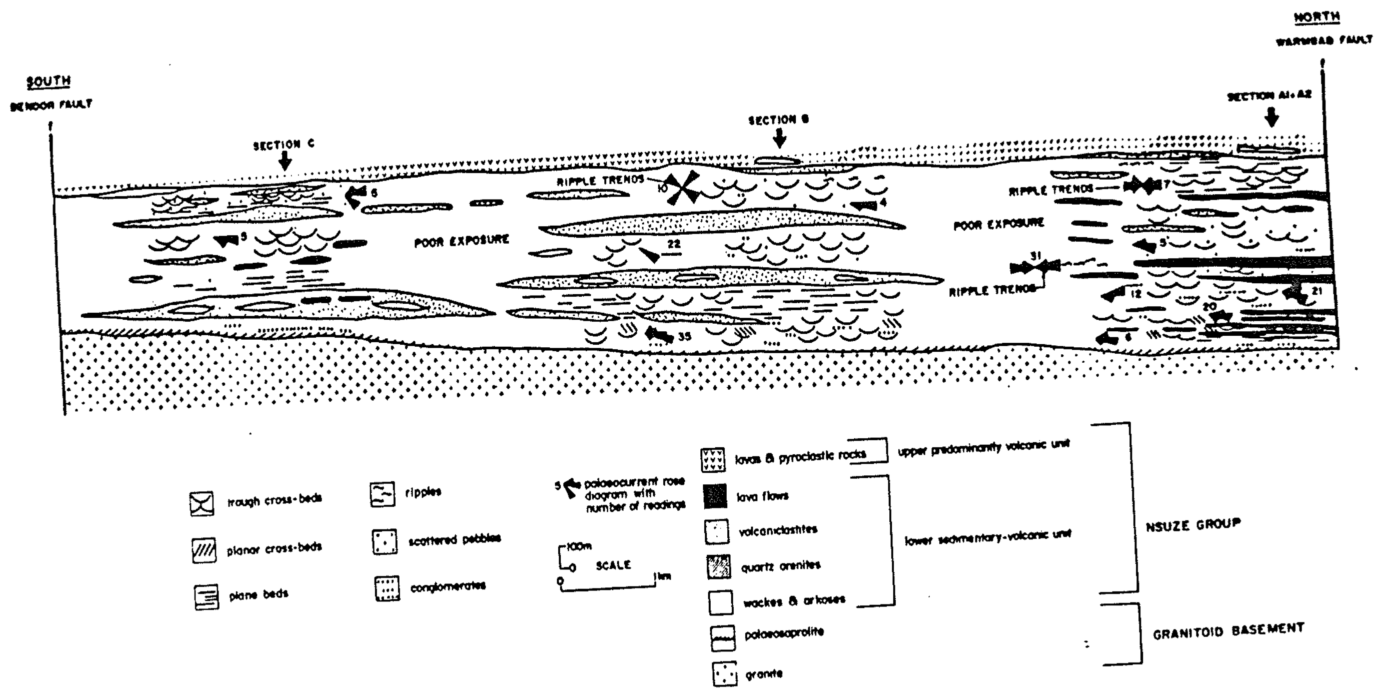

Fig. 2. Sedimentology of the lower sedimentary-volcanic unit, Nsuze Group. Section shown is between the Warmbad and Bendor faults. After Armstrong (1980).

1.5 A Palaeoenvironmental Reconstruction

The overall nature of the clastic rocks at the base of the Nsuze Group indicates deposition in a distal braided stream environment. The preponderance of trough cross-stratification indicates that individual channels had low sinuosity, despite the fact that the overall sedimentation was apparently dominated by an undulating topography. The formation of a tabular sandstone, almost devoid of mudstones, suggests rapid lateral migration of channels, presumably in an active tectonic environment (Fig. 2).

There is evidence to attest that the major river channels were dominated by migrating dunes with development of transverse bars in the shallower reaches. Gravel lags were developed within the channels, which at times aggraded to form longitudinal bars. Thin overbank deposits developed away from the channels, but it would seem as if these deposits had little potential for preservation. Sheet wash as a result of high precipitation was prolific as a result of lack of vegetation. Lenticular quartz arenites conceivably represent major channels, occupied for extended periods and subsequently reworked.

Volcanic rocks were extruded from vents located to the north of the study area (Fig. 3). All of the lava flows are thin and impersistent suggesting extrusion from crater cones or small fissures. Pyroclastic material was ejected to considerable heights in the air from vents situated either on land or in shallow water. These fragmental ejections were winnowed during wind transportation prior to deposition on the braided alluvial plain. The volcanogenic sediments were formed by reworking and mixing of pyroclastic debris with fluvial detritus. The volume of volcanic rock seems insufficient to have supplied all the sediment, the bulk of which was possibly derived from a granite-greenstone source.

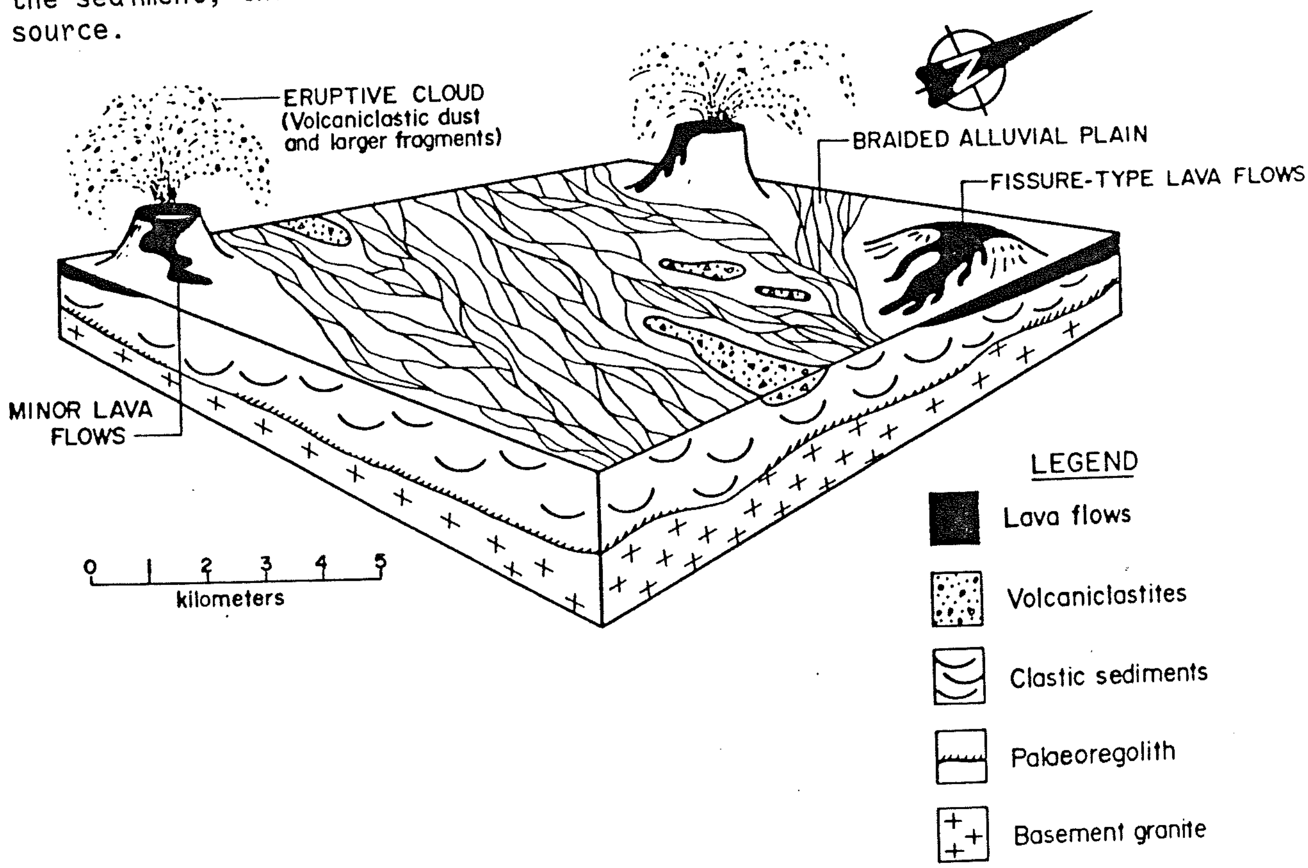

Fig. 3. Diagrammatic palaeoenvironmental reconstruction of the lower sedimentary-volcanic unit of the Nsuze Group. After Watchorn and Armstrong (1980).

2. Middle Volcanic Unit - Bivane Formation

The middle volcanic unit, comprising about 90% of the total thickness of the Nsuze Formation, is characterised by effusive volcanism accompanied by subordinate explosive volcanic activity and some clastic sedimentation. The lavas consist of basalts, basaltic andesites, andesites, dacites and rhyolites. The volcaniclastics include pyroclastic, autoclastic and hyaloclastic rocks and the intercalated sediments are mainly sandstones with minor argillites.

A maximum thickness of 7 500 m has been estimated for the middle unit of the Nsuze Group, but in places it could be as thin as 6 000 m. Estimates of thickness are hampered by the paucity of continuous exposures showing regular dip surfaces, the tectonic flattening accompanied by steepening of strata, and also the presence of intrusions and cover rocks. The thickness of individual lava flows were found to be less than 50 m where contacts could be identified. Flows of both similar and different compositions are complexly interfingered on both regional and local scales.

The basalts are fine-grained rocks in which the primary ferro-magnesium minerals are replaced by amphibole and chlorite. Advanced saussuritization has affected the plagioclase in most basalts. Titaniferous magnetite altered to leucoxene and sphene is a common accessory mineral. Some basalts contain small (less than 5 mm diameter) spheroids of finer grain size and are compositionally similar to the groundmass in which they occur.

Basaltic andesites constitute the most common rock-type in the Bivane Formation. These rocks are grey-green and typically porphyritic. Phenocrysts of plagioclase occur as robust euhedral laths up to 3 cm in length, or alternatively short, lath-shaped crystals in clusters imparting a glomeroporphyritic texture. The groundmass comprises chlorite, biotite and minor actinolite. Epidote is more abundant than in the basalts and sphene is common as an accessory. The plagioclase is saussuritized under low grade metamorphism. Flow banding is present in some basaltic andesites.

The andesites are similar in appearance to the basaltic andesites, and the dacites are distinguished from the andesites by their grey colour. Phenocrysts of oligoclase are prominent in the dacitic flows in which quartz also occurs as rare, corroded and resorbed phenocrysts.

Rhyolites are easily recognised by their dark colour and brittle nature. Devitrification and recrystallisation have considerably modified the rhyolites. The groundmass comprises a fine-grained, granular mosaic of quartz, felspar and sericite. Minor amounts of chlorite, epidote and sphene are present and zircon and apatite are the accessory minerals.

Quartz-felspar porphyries are associated with some rhyolitic flows.

The extrusion of the Nsuze lava flows was probably continuous from a number of vents. There are only very minor sedimentary intercalations within the Bivane Formation and these sediments commonly support evidence of contemporaneous volcanicity during sedimentary deposition, as indicated by fragmental pyroclastic inclusions and hyaloclastic intervals. However, these sedimentary rocks have not been studied in detail. This is principally due to poor exposure and the impersistent nature of the sediments.

3. Upper Volcaniclastic-Sedimentary Unit - Roodewal Formation

The relationship between the Nsuze and Mozaan Groups in the study area is represented by a transitional zone identified as the Roodewal Formation. The

Mozaan Group is disconformable on the Nsuze Group to the north and south of the area discussed here.

The Roodewal Formation varies in thickness from 5 to 600 m, and comprises a number of complexly interfingering facies, representing both pyroclastic and sedimentary deposition.

The Roodewal Formation is dominated by fine-grained rocks which include argillites and air-fall tuffs, with arenaceous and volcanic lenses. The term volcanogenic sediments has been given to the fine-grained rocks that are composed mainly of sedimentary and pyroclastic debris. No clear distinction can be made between these rocks because of their poor outcrops. Intercalated with these volcanic sediments are lenses of epiclastic volcanic breccia, accretionary lapilli tuffs, arenaceous sediments and minor lava flows.

The air-fall tuffs form impersistent lenses varying in thickness from 2 to 50 m. Lenses of arenaceous and argillaceous rocks are generally poorly exposed. The arenaceous lenses are quartz wackes which display plane bedding as well as cross-stratification.

Dacitic to rhyolitic lava flows, less than 5 m thick, are occasionally present with the associated pyroclastic units.

4. A Palaeoenvironmental Reconstruction of the Bivane and Roodewal Formations

It has previously been noted that with regard to the Wagendrift and Mantonga Formations of the Nsuze Group, sedimentation essentially ceased with degradation of the continental crust.

With regard to the Bivane Formation, exhibiting a thick pile of accumulated lavas, it must be noted that no extrusive centres can be identified within the Nsuze Group. It is conceivable that volcanic edifices were engulfed and collapsed during subsidence of the basin during Nsuze deposition. Alternatively, the vents are not exposed at the present level of erosion.

It is only the nature of the volcanism that points to the possible types of volcanic vent. The paucity of basic pyroclastics attests to the relative quiet extrusion of these lavas which presumably reached the surface by way of fissure systems. Furthermore, the viscous acid magmas, associated with a variety of pyroclastic rocks could have extruded through the same fracture systems or may have been related to small cone-like vent structures. However, the extrusion of Nsuze lavas under essentially sub-aerial conditions is evidenced by the following factors:

. the lavas overlie fluvial sediments,

. the absence of pillowed lavas,

. the abundance of fine-grained, air-fall pyroclastics, devoid of sedimentary structure, and

. the lack of major sedimentary intercalations.

It should be noted, however, that despite the lack of subaqueous indicators, no flow type lavas have been recognised.

Subsidence of the Nsuze basin in response to the thick accumulation of middle (Bivane Formation) Nsuze lavas, apparently continued after depletion of the feeder magma chambers. The Upper Nsuze unit (Roodewal Formation) is characterised by explosive volcanicity with only minor intercalated vesicular lavas. This suggests that in the latter stages, subsidence was not accompanied by significant lava extrusion, and as a result, therefore, small depressions could be expected to form. These depressions were filled with water in which deposition occurred of sediments derived both from pyroclastic ejectamenta and the weathered products of exposed Nsuze volcanics, and transported in immature fluvial systems to the above suggested depositories.

Upon final exhaustion of the magma chambers, a large shallow basin developed in which the Mozaan Group sediments were deposited.

Mozaan Group

1. Previous Work and General Geology

Humphrey and Krige (1931) constructed a composite section for the Mozaan Group in the Vryheid-Piet Retief district, describing a 5 000 m thick sequence of alternating arenaceous and argillaceous rocks with a volcanic member near the top. Furthermore, Humphrey and Krige (1931, 1932) described the Mozaan in this region as cropping out in two structural basins, separated by a northwesterly-trending fault. The absence of Nsuze volcanics in the east, as opposed to the relatively undisturbed western margin of the basins, is ascribed by these authors to assimilation by post-Pongola granite.

The detailed mapping by Watchorn (1978) has more clearly defined the two structural basins, in the northeast (Piensrand basin) and the southwest (Hartland basin). This mapping confirms these basins are separated by a tight (Altona) anticline and according to Mathews (1990) by some major faulting. The Piensrand basin is dissected by the extensive intrusive Spekboom granite which cuts across the southeastern part of the Mozaan basin and separates the main Mozaan Formation from those outcropping to the west of Magudu (See Map 1).

Most of the arenaceous sediments in the Mozaan Group are orthoquartzitic, but generally subordinate arkoses and greywackes are also present. These sandstones are mostly medium- to coarse-grained and sporadically contain intercalated pebble stringers. In places sedimentary structures are preserved and can be identified and measured.

The argillaceous units comprise both mudstones and siltstones, and these tend to be more ferruginous towards the base of the Mozaan Group. Occasional oxide facies banded iron formation is associated with these iron-rich argillites.

The volcanic units of the upper Mozaan consist of both amygdaloidal and non-amygdaloidal lavas of acid to intermediate composition. Medium to fine-grained pyroclastics are also present.

The Mozaan Group in the complex Pongola Basin has been subjected to two episodes of basic intrusion. The older diabases are conceivably related to the Usushwana igneous event, whereas the younger dolerites are of Karoo age.

2. The Lithostratigraphy

Watchorn (1978) points out that as a result of the complexity of the structural geology, lateral correlations of the Mozaan stratigraphy was impossible. This led to emphasis being placed on the construction of a realistic stratigraphic column for the Mozaan Group, and to interpret the broad depositional environment.

According to SACS (1980), the Mozaan Group in the area of the Pongola-Mozaan valleys has been subdivided into eight Formations which from the base up are referred to as the Ozwana (150 m)-consisting of phyllites and basal conglomerate; Singeru (610 m) - quartzites and iron formation; Ntomba (1 535 m) - shales, with thin quartzites and iron formation; Thalu (305 m) - quartzites and thin iron formation; Ceba - (760 m) - quartzite and shales; Hlashana (105 m) - quartzites; Odwaleni (2 680 m) - quartzite and shales and the Nkwemi (680 m) - grey sandstones. The total thickness according to this subdivision is some 6 225 m. According to Watchorn (1978) the stratigraphic column is about half this thickness at some 3 000 m, whereas Mathews (1990) suggests a thickness of 4 600 m.

Despite the detailed stratigraphic mapping of Watchorn, SACS (1980) has made no attempt to fit the eight Mozaan Formations to his stratigraphic column. More recent mapping by Linström and Marshall (1982) has raised doubt as to the validity of the upper six Formations listed above for the Mozaan Group.

As stated by Watchorn (1978), the best exposed and most continuous stratigraphic section through the Mozaan Group is along the Mozana River. A representative stratigraphic column for the Mozaan Group in the Vryheid-Piet Retief area is shown in Fig. 4. When the stratigraphic thickness of the study area of Watchorn (1978) is compared with other mapped areas of Mozaan rocks within the Pongola basin, it is clearly apparent that the Mozaan Group is best developed in the Vryheid-Piet Retief region.

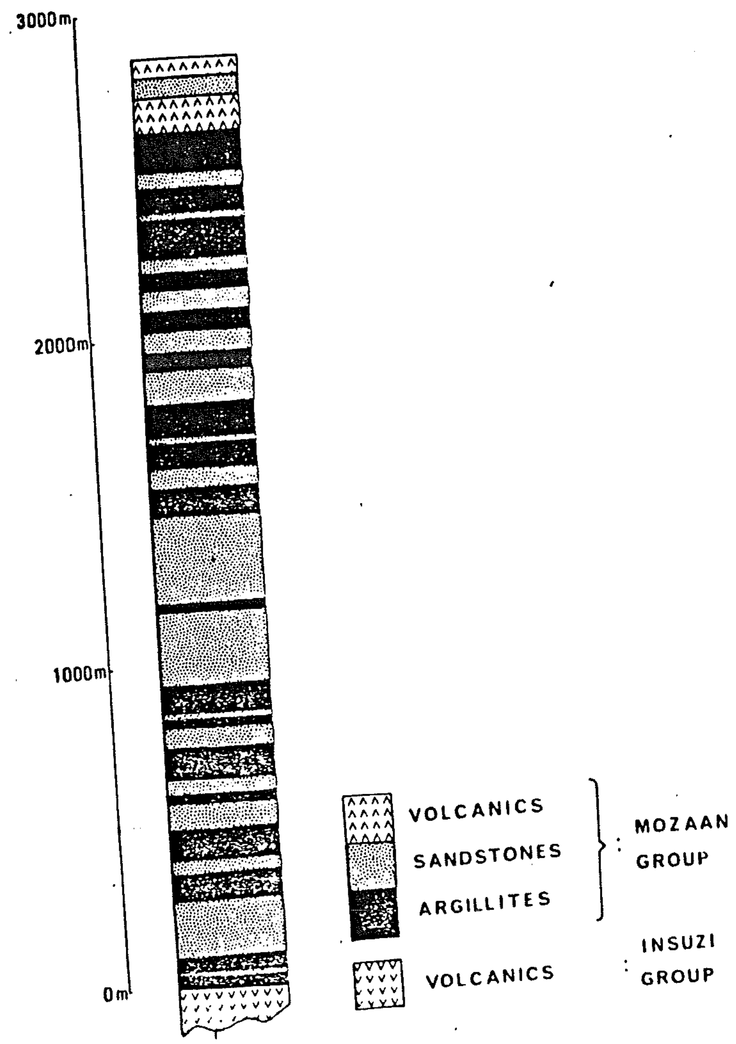

Fig. 4. Representative stratigraphic column for the Mozaan Group in the Vryheid-Piet Retief area

After Watchorn (1979)

A comparison of the sandstone to shale ratios from several studied sections shows a pronounced fining southwards pattern from Swaziland to the Vryheid-Piet Retief districts. This is also in accord with the palaeocurrent measurements, which imply a north to northwesterly provenance area. The above data suggests that the depocentre for the Mozaan basin was located in the Vryheid-Piet Retief area.

Watchorn (1979) has investigated the contact between the Nsuze and the Mozaan and has concluded that there is a strong likelihood that the transition from Nsuze volcanics to Mozaan sedimentation was gradational. The transition is characterised by an upward decrease in pyroclastics with concommitant development of sandstone lenses. The presence of a lenticular porphyroblastic andalusite schist in the contact zone is of interest, and suggests Al_2O_3 possibly concentrated by soil leaching in an area removed from active sedimentation. Therefore, the presence of an andalusite schist in the Mozaan may be indicative of a palaeoregolith, marking a disconformity.

3. Sedimentary Facies

The Mozaan comprises intercalations of arenites and argillites within which nine sedimentary lithofacies were distinguished on the basis of composition, texture and sedimentary structure (Watchorn, 1978; 1979). These nine lithofacies are shown on the accompanying figures (Figs.4, 5 and 6) as A1-A3 for the braided alluvial plain; B1-B3 for off-shore shelf and C1-C3 for the tidalite, interacting depositional environments.

Braided Alluvial Plain (Fig. 5)

Planar cross-bedded and plane-bedded quartz arenites are the dominant characteristics of this facies assemblage, but less mature sandstones are also present. Occasionally, this assemblage overlies or is overlain by thick sequences of mudstone. The dominance of planar cross-stratification, displaying an unimodal southerly palaeocurrent pattern, combined with the paucity of fine-grained sediment and the absence of vertical textural trends are typical of distal braided reaches.

This facies further displays angular and tangential planar foresets, with the latter accompanied by regressive ripples. It is suggested that these latter structures suggest fluctuations in sediment load, reflecting possible low and high water stages respectively.

Plane beds, often superimposed on planar cross-bed sets are interpreted as bar-top sediments formed in response to vertical accretion. Cross-cutting channels containing trough cross-beds are indicative of the braided stream environment.

Minor, lenticular matrix- and clast-supported conglomerates are interbedded with the sandstones. The conglomerates attain a maximum thickness of 2 m with individual pebbles (angular to subrounded) less than 15 cm in diameter. These conglomerates are interpreted as longitudinal bars formed during periods of extreme discharge.

The rare lense-like shale interbeds, up to 30 cm thick, are suggestive of abandoned channel deposits. The infrequencey of the intercalated argillaceous sediments is another characteristic feature of braided stream environments.

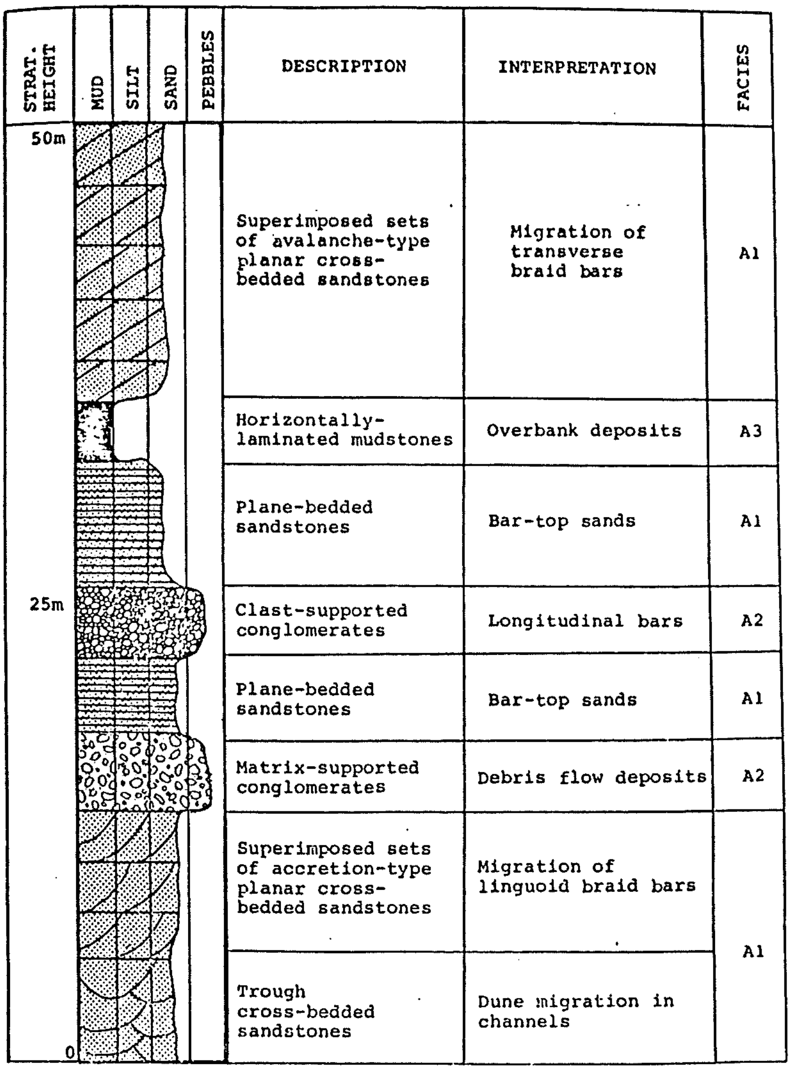

Fig. 5. Idealized stratigraphic section and palaeo-environmental interpretation for depositional Model A - the braided alluvial plain.

After Watchorn (1979).

Progradational Shelf (Fig. 6)

The lithofacies are expressed as an upward-coarsening sequence with lenticular bodies of iron formation as the lowermost unit. The iron formation comprises a rhythmic interlamination of magnetite and grey chert or jasper, which locally are contorted. Parallelism of these contorted beds and the regional structure suggest tectonic deformation. The generally poor development of the banded iron formation may be a function of a high rate of supply of clastic sediment. Mention should be made of the fact that banded iron formations are of widespread occurrence within the Mozaan Group, but are restricted to the lower parts of the stratigraphy. According to Beukes (1973), the aluminium-rich sedimentary rocks associated with the iron formations of the Pongola Supergroup, suggests that intensive weathering of the source area took place, with a virtual complete separation of the major elements. It is further suggested that the silica in the iron formation was derived from acid volcanism. This is supported by the observation that banded iron formations are confined to the basal parts of the clastic sedimentary rock units overlying mafic to felsic volcanic units, which formed during the initial evolutionary development of the basin.

Enveloping the banded iron formation is a sequence of black shales with occasional jasper or chert lenses. These latter rocks are often magnetic when positioned in the lower Mozaan stratigraphy.

According to Watchorn (1979), the relationship of the banded iron formations and the overlying facies would indicate the black shales to have been deposited on a distal shelf where chemical precipitation and clastic fall-out took place contemporaneously.

Above the shales occur a gradational sequence of some 200 m of interlaminated shales and rippled siltstones with occasional interbedded sandstones. Interference ripples and pronounced polymodal ripple trends suggest the flow patterns were complex and very likely modified by the subaqueous relief on a proximal shelf environment.

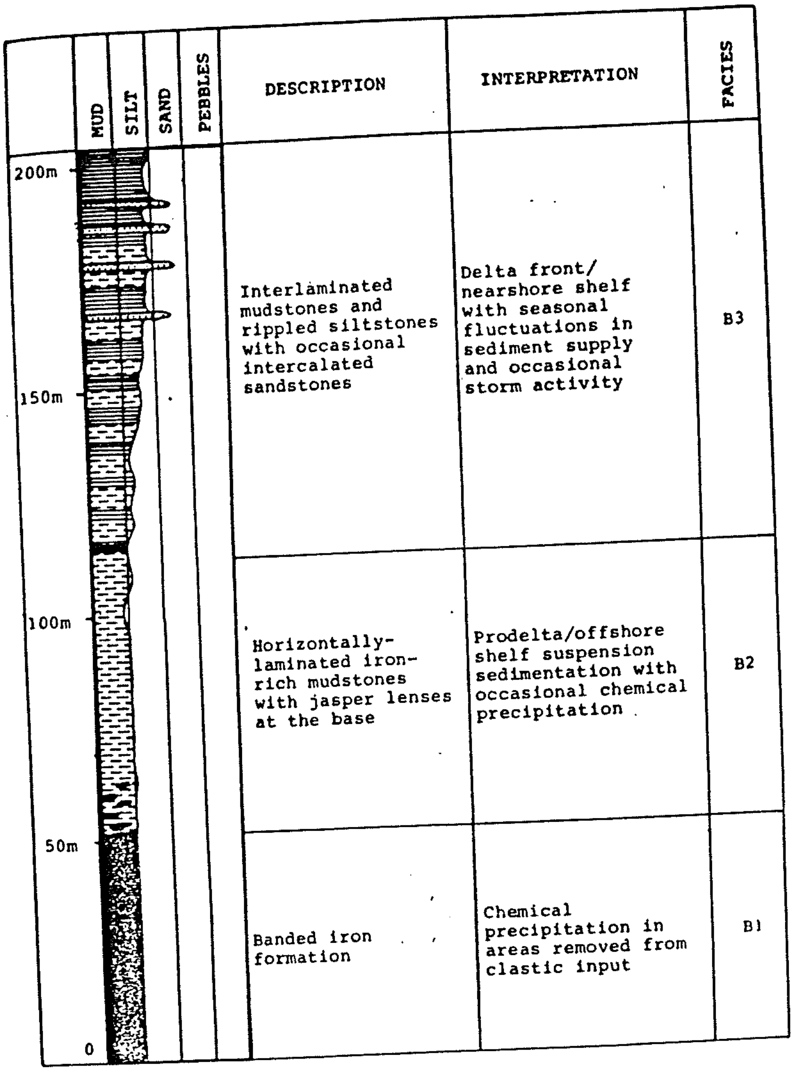

Fig. 6. Idealized stratigraphic section and palaeo-environmental interpretation for depositional Model B - the shelf deposits.

After Watchorn (1979)

High tidal flat environment (Fig. 7)

This model is expressed by three lithofacies, forming a fining-upward sequence. The facies have gradational contacts with each other as well as with the underlying progradational shelf environment.

The proximal shelf is gradationally overlain by quartz arenites which characterise the base of the tidal sediments. These sandstones are of medium to coarse-grain and are well-sorted and have rounded clasts, probably due to extended transportation caused by oscillatory tidal motion. However, these textural and mineralogical properties cannot be considered diagnostic of the tidal environment, since the Mozaan has a significant sedimentary provenance area.

According to Watchorn (1980) several diagnostic sedimentary structures associated with a typical upward-fining cycle are strongly supportive of a tidal environment, and he gives pertinent literature study support for his statement. With reference to Fig. 7, the basal planar and trough cross-bedded facies are interpreted as a subtidal sand bar across which sand waves and dunes migrated. The overlying plane beds, flat-topped megaripples and interference ripples are accompanied by mud drapes and indicate late stage emergence runoff and aids to distinguish intertidal from subtidal areas.

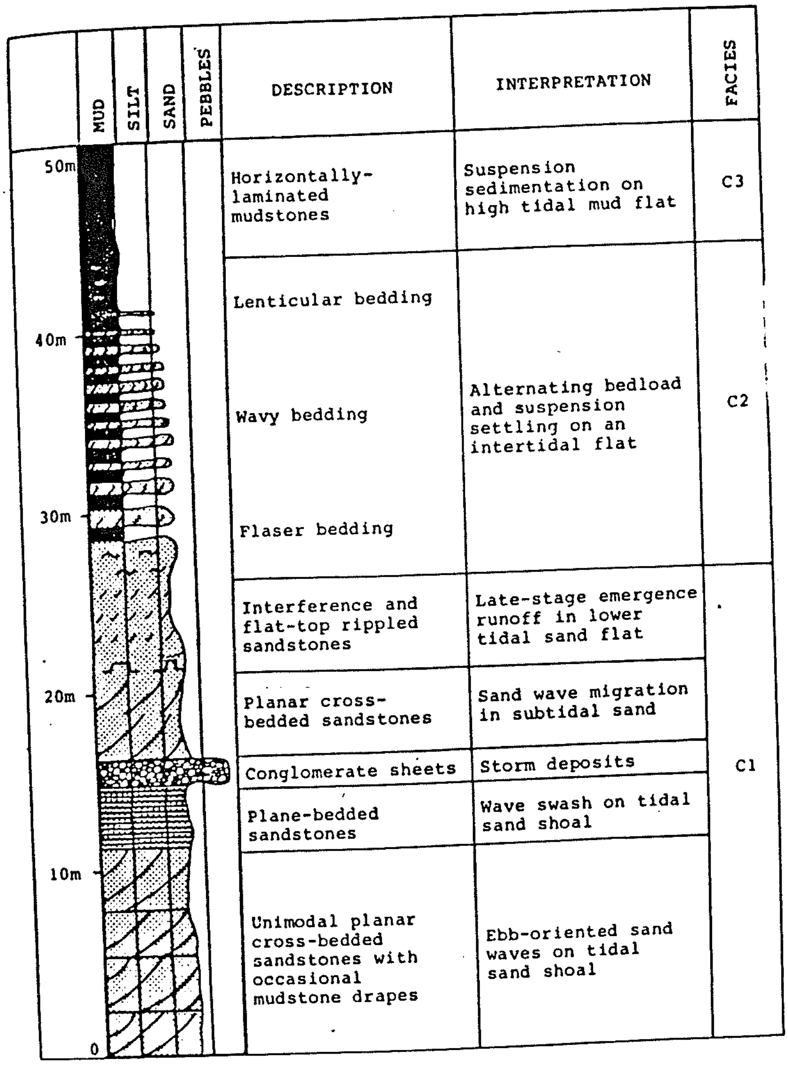

Fig. 7. Idealized stratigraphic section and palaeoenvironmental interpretation for depositional model C - tidal assemblage

After Watchorn (1979)

Overlying the flat-top rippled sandstones is a heterolithic facies consisting of interlaminated sandstones and shales, with an increasing shale component near the top. Similar sequences have been noted elsewhere and identified as mid-tidal flats. Capping the stratigraphic section are black massive or laminated shales which are interpreted as high tidal flat deposits.

Due to deformation in the Mozaan Group, all palaeocurrent data had to be palinspastically restored to the horizontal. Most of the information relating to the palaeocurrents were obtained from planar cross-beds, although trough cross-beds were also utilised where possible. The resultant data display two dominant trends, one towards the south or southeast and the other towards the east or northeast. The former trend is believed to indicate southward flowing braided streams passing basin-wards into ebb-dominated tidal currents. The easterly directed trends are interpreted as having been formed by tidal sand bodies which developed parallel to depositional strike. The weak northerly trend is possibly indicative of occasional preservation of flood directed tidal currents.

From the interpretations outlined above regarding the constituent depositional models, it would seem apparent that during Mozaan times, sedimentation was dominated by two interacting environments, namely the braided alluvial plain and a tide-dominated marine basin (Fig. 8). In the study area of Watchorn (1979), it would appear as if only the distal reaches of the fluvial environment was developed. Under normal flow conditions, the braided rivers were characterized by southward accreting transverse bars. However, fluctuations and increase in flow rate influenced bar modification to linguoid forms and sporadic low density debris flows.

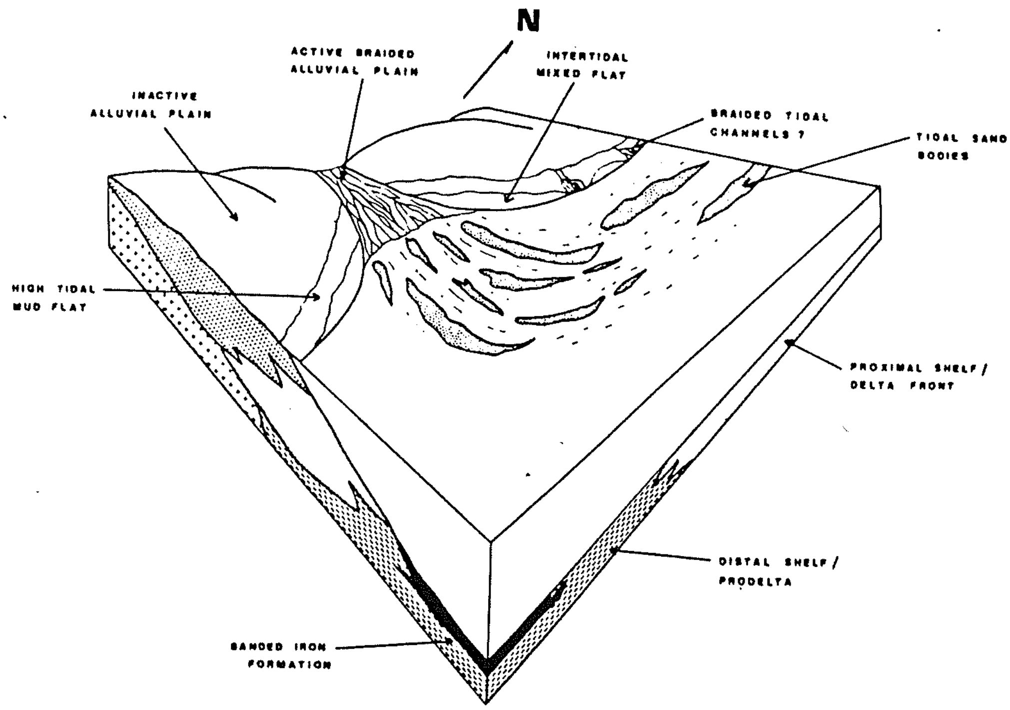

Fig. 8. Palaeogeographic model for the Mozaan Group in the Vryheid-Piet Retief area

After Watchorn (1979)

Directly underlying the tidal sediments is an upward-coarsening shelf assemblage. Both of these environments have been subjected to periodic storm activity. However, the absence of turbidites in the shelf deposits seems to suggest that the Mozaan basin can be regarded as a shallow inland sea. The fact that macrotidal activity influenced the sedimentation would imply that the Mozaan depository was connected to an open sea, and that tidal range was then influenced by resonance and the effective increase in shelf width.

From the aspects of the gross-vertical facies distribution, the Mozaan Group presents an overall southeasterly progradational sequence. This model finds support from the fact that the maximum development of the shelf sediments occur in the lower Mozaan stratigraphy, whereas the fluvial deposits characterise the top of the sequence. This probably reflects a gradual infilling of the basin through time.

Central Domain

Exposures of Nsuze and Mozaan Group rocks of the Pongola Supergroup within the Central domain are confined to a cluster of widely separated erosional inliers. Although considerably scattered, a general NW-SE structural trend is apparent within these inliers, and the overall geology reveals a system of SW tilted fault blocks consisting of granite-greenstone basement overlain unconformably by Pongola Group assemblages dipping at angles of 5-30 degrees, generally to the NE but occasionally to the SW. These relationships are shown on the cross-section in Fig. 9A, which is based on data from the Wit Mfolozi and Thaka inliers.

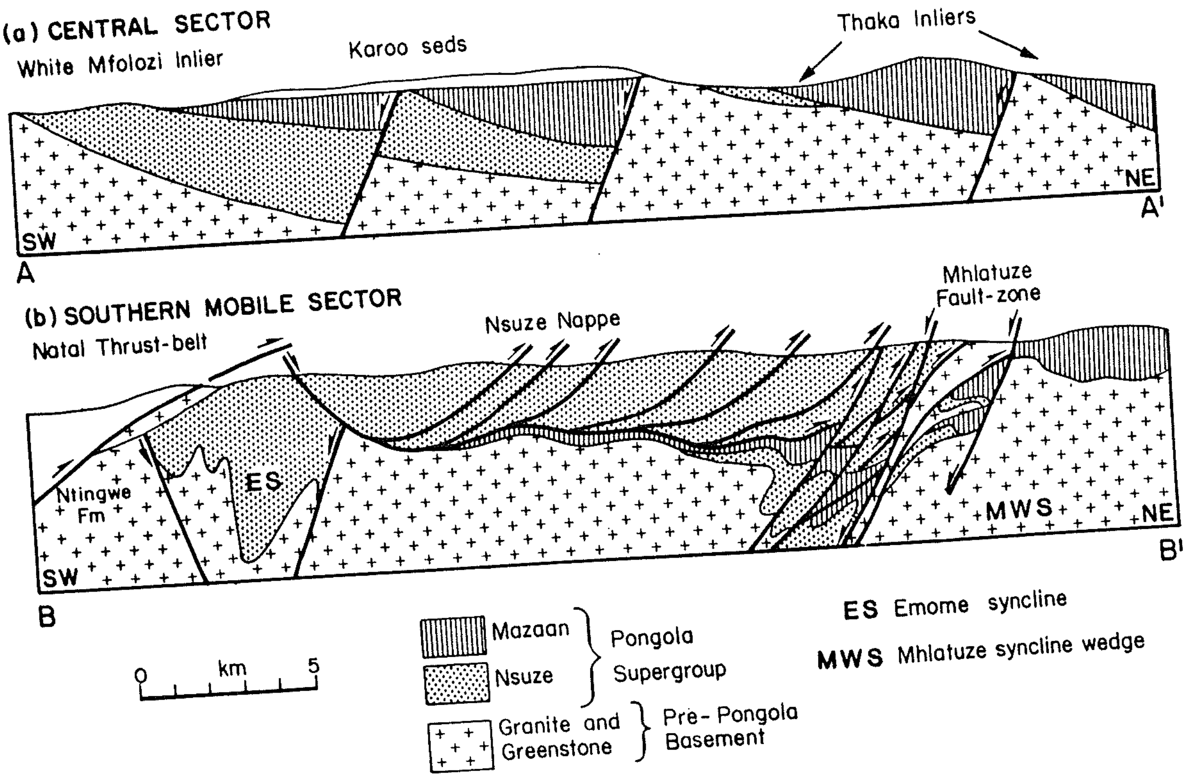

Fig. 9. Sections across the central and Southern structural domain of the Pongola Supergroup

Simplified after Mathews (1990).

The stratigraphic relationships within these inliers of the Pongola Supergroup clearly indicate that the Nsuze Group has been overlapped from the north and south by the Mozaan sequence. The mapping of Mathews (1967) has revealed that the southward overlap in the Wit Mfolozi inlier involves a southward overstepping relationship along a NE dipping low-angle unconformity. This unconformity displays a strike of less than 5 degrees between the strata above and below.

As a consequence of covered intervals between successive inliers, the nature of the northern overlap cannot be identified. The presence of the overlap, however, is quite clearly indicated by virtue of the absence of the typically volcanic Nsuze Group in the Thaka inlier, whilst the Nsuze Group attains a maximum thickness of about 2,5 km in the Wit Mfolozi inlier some 35 km to the SE. Within the Thaka inlier, the Pongola sequence is represented by an alternating succession of sandstones and siltstones of the Mozaan Group, dipping to the NE at 5 to 10 degree, resting unconformably on a vertical to steeply inclined greenstone assemblage of banded cherty quartzites, basic schists and phyllites.

Based on the overlap relationships in the Central domain it is suggested that southward expansion of the Mozaan depository occurred after the southern region of the Nsuze basin had undergone uplift and erosion. It is suggested that fairly large scale warping at this time conceivably produced structures such as the prominent basement arch along the southern flank of the Mfolozi inlier. This structural feature forms the boundary between the central and southern domains of the Pongola Supergroup. Other than the Thaka inlier which has not been studied in any detail, the remaining inliers within the Central domain are described below.

(1) Mpongoza Inlier

The Mpongoza Inlier has been studied in considerable detail by Preston (1987). Earlier investigations of this inlier were confined to lithological descriptions of specific sections of the stratigraphy and some depositional models by von Brunn (1974) and von Brunn and Hobday (1976).

The Mpongoza inlier, correlated with the Nsuze Group, has been informally subdivided into a lower volcanic unit (2 560 m), a clastic sedimentary unit (260 m) and an upper volcanic unit (720 m) respectively.

1(a) The lower volcanic unit consists predominantly of felsic volcaniclastic rocks underlain by subordinate mafic lavas, and is subdivided on the basis of lithological differences into the northern and southern facies some 1 000 m and 1 560 m thick respectively. The northern facies consists of amygdaloidal mafic lavas ($\pm$ 300 m) overlain by felsic volcaniclastics ($\pm$ 700 m). The southern facies comprises amygdaloidal mafic lavas some 140 m thick, overlain by a prominent succession of felsic volcaniclastic rocks some 1 420 m thick which can be subdivided into three simple cooling units.

1(b) The sedimentary unit attains a thickness of 260 m and comprises two sandstone sub-units, interbedded with a heterolithic sub-unit. A 25 to 35 degree southeasterly dip of the bedding surfaces probably reflects a reliable indication of the overall attitude of the lithostratigraphic sequence of the Mpongoza inlier.

The sandstones are medium to coarse grained and variably sorted. The quartz arenite sub-unit located at the base of the sedimentary unit, is up to 100 m thick and grades conformably into the overlying heterolithic sub-unit which in turn is unconformably overlain by a second quartz arenite sub-unit up to 85 m thick.

A variety of sedimentary structures provide valuable data pertaining to the palaeoenvironmental setting. Ripplemarks on sandstone and siltstone bedding surfaces are the most prominent structures. Sandstone-filled rectilinear cracks are characteristic of the heterolithic sub-unit and mudstone flakes are also ubiquitous in this sub-unit where they are embedded in arenaceous layers. In addition to the above, flaser, wavy and lenticular bedding is also developed.

Furthermore, sedimentary structures including planar and asymtotic cross-beds in the sandstones are those generally associated with deposition under flow regime conditions.

A depositional model for the Mpongoza sedimentary assemblage must take account of the different lithofacies in terms of grain size, textural maturity and composition. Also the overall upward-fining trend from quartz-arenite to the succeeding heterolithic sub-unit must receive consideration.

The lithologies and associated sedimentary structures listed above are indicative of deposition in a tidal palaeoenvironment. Tidal deposits of the Pongola Sequence appear to have covered a large area prior to tectonism and subsequent burial by younger sediments. According to von Brunn (1974) and von Brunn and Hobday (1976), the Mpongoza sedimentary section vertical facies arrangements reflect three possible intertidalite sequences.

1(c) <u>The upper volcanic unit</u> (± 1 160 m) comprises a 480 m thick sequence of mafic lavas overlain by 680 m of felsic volcaniclastic rocks. The sequence is capped by a thick block and ash deposit. The mafic lavas are proportionally equal in volume to the felsic volcaniclastic rocks, unlike such relationships in the lower volcanic unit.

1(d) <u>Correlation and depositional environment</u>. The Roodewal Formation (Nsuze Group) in the Northern domain (Piet Retief area) is described by Armstrong (1980) as comprising volcaniclastic, volcanic and sedimentary rocks considered to be representative of terminal explosive degassing of the depleted magma chamber. Although this, the Roodewal Formation, is thinner than that observed in the Mpongoza inlier, i.e. some 500 m as opposed to 3 220 m,, the rock-types and general characteristics of the volcanic style is suggestive of a potentially valid lithostratigraphic correlation between the two areas. It follows therefore that the volcaniclastic rocks of the Mpongoza inlier may be interpreted as subaerial pyroclastic flows characterising the terminal volcanic stage of the Nsuze Group.

As will be discussed in a later section, it is evident that the Nsuze Group in the Wit Mfolozi inlier comprises subaqueous lavas intercalated with a subordinate quartzite-dolomite bed containing a tuffaceous sandstone layer. In the Southern domain (i.e. Nkandla area), the Nsuze Group comprises tuffaceous sandstone, clastic sediments and minor lava. It is reasonable therefore to regard the volcaniclastic component of the tuffaceous sandstones in the Southern domain as being either locally derived or an extreme distal extension of the pyroclastic flows in the Mpongoza inlier.

The sediments associated with the Nsuze Group volcanics are of considerable importance as indicators of the palaeoenvironment. We have previously discussed that the sedimentary sequence associated with subaerial volcanism in the Northern domain (Piet Retief area) represents a fluvial braided system which drained to the south and southeast. Minor lava flows associated with this sedimentation initiated a major period of volcanism. It is of importance to note that the field studies show that the magnitude of the clastic sedimentation increases very markedly in the Nsuze from the Northern to the Southern domain over a distance of some 200 km. Furthermore, the sedimentary units in the Southern Domain can be regarded as substantial accumulations of shallow marine sediments that were subjected to strong tidal currents during deposition across a wide subsiding shelf, Mathews (1990). It would seem therefore that there is a progressive palaeoenvironmental change in the Nsuze Group from subaerial type deposition in the Northern domain to subaqueous emplacement in the south. This data suggests that the Mpongoza sequence (Central domain) is located about midway between the northern and southern extremities of the Nsuze Group occurrences and therefore represents an intermediate environment comprising intertidalites and subaerial volcaniclastic rocks, which form the southern margin of the subaerial felsic pyroclastic volcanism.

(2) Wit Mfolozi Inlier

The Pongola Sequence in this area is represented by rocks of both the Nsuze and Mozaan Groups. The latter rests with a slight angular unconformity on the Nsuze Group. The overall succession was described in some detail and subdivided by Mathews (1967, 1977) and SACS (1980).

2(a) Nsuze Group. Resting with an unconformable contact on the granite pre-Pongola basement, the Nsuze Group comprises six formations (SACS, 1980). These formations consist of an alternating sequence of sedimentary and volcanic rocks with the total thickness of the group probably exceeding 3 500 m (Linström, 1987). The lithological subdivision as set out by SACS (1980) provides the basis for the following account of this Group.

2(a. 1.) Basal member (Bomvu Formation)

The basal member of the Nsuze is a thin (0-60 m), but extensive deposit of clean, well-bedded quartzitic sandstone with occasional arkosic layers near the non-conformable contact with the pre-Pongola basement. These beds dip to the northeast at 15 to 35 degrees and have an extensive strike extent. The limited thickness and lateral persistence testify to the extreme planation of the sub-Nsuze surface in the area. In places an impersistent, thin and frequently single-layer conglomerate, containing well-rounded quartz pebbles, is developed at the base of the Bomvu Formation.

The evidence suggests that the basal quartzites of the Nsuze observed in the Mfolozi inlier represent a thin transgressive deposit, consisting of coastal sands which were reworked by long shore currents in a near littoral environment (Mathews, 1967).

2(a. 2) Lower volcanic zone (Nhlebela Formation)

This zone is an accumulation of aphanitic lavas up to 120 m in thickness. Pillow-structures have been noted. These lavas rest with a sharp contact mainly on the basal quartzites, but occasionally also on the pre-Pongola basement. The lavas of the Lower and Upper Volcanic zones of the Nsuze Formation within the Mfolozi inlier are similar.

2(a. 3) Banded Shale zone (Thembeni Formation)

A group of predominantly argillaceous sediments up to 240 m thick overlie the Lower Volcanic Zone. Small-scale ripple-drift bedding is the main feature of the shales forming most of this zone, and imparts a finely laminated appearance. In a localised area the shales contain intercalations of pebbly grits and sandstones, the basal layers of which are conglomeratic. The laminated ripple-drift structure of the shales is indicative of intermittent turbulence in a tidal flat environment.

2(a. 4) Quartzite-dolomite zone (Chobeni Formation)

This zone indicates an abrupt change in the depositional regime, characterised by the sharp and conformable contact between this zone and the underlying banded shales.

The Quartzite-dolomite Zone is some 760 m thick and consists predominantly of quartzitic sandstones. Within the environs of the Wit Mfolozi valley, however, these sandstones are replaced along strike in both directions by carbonate-bearing, tuffaceous sandstones, carbonate-cemented sandstones, carbonate mudstones and several units of dolomite. These carbonates are of particular interest as no other Nsuze Group exposures contain dolomites. The occurrence of stromatolites associated with the dolomite has been described in some detail by Mason (1977). The Nsuze Group stromatolites are of considerable interest considering the paucity of biogenic structures of Pongola age ($\pm$ 3 000 Ma) in the geological record. Partings of silty shale are present near the top of the Chobeni Formation.

2(a. 5) Upper volcanic zone (Bivane Formation)

This zone consists almost exclusively of dark to pale green lavas, generally amygdaloidal and with occasional pillow structures. A thin intercalated wedge of sandstones is situated some 300 m above the base of the lavas. The Upper volcanic zone attains a maximum thickness in excess of 2 050 m. The sediments and the amygdaloidal zones and lenses in the lavas are inclined consistently to the north-east at 20 to 26 degrees. This orientation is similar to the dip of the underlying strata and suggests that the Upper volcanic zone follows conformably on the Quartzite-dolomite zone. Individual lava flows can be recognised by the presence of well-developed amygdaloidal zones near their bases and tops.

2(a. 6) Quartzites and Shales (Thaka Formation)

Inliers of ferruginous shale with thin intercalated quartzite in excess of 530 m in thickness, constitute the uppermost formation of the Nsuze Group.

2(b) Mozaan Group

The Mozaan Group within the Mfolozi inlier, consists essentially of a lower group of arenaceous and an upper group of argillaceous sediments with an estimated thickness of some 1 200 m. The Mozaan rests unconformably on rocks of the Nsuze and is in turn unconformably overlain by flat-lying Karoo strata. The Mozaan succession dips on the average east-north-eastwards at 5 to 10 degrees, and attains a maximum exposed thickness of approximately 1 200 m. When traced south-eastwards the basal beds of the Mozaan overstep some 1 200 m of Nsuze strata. The characteristics of the Mozaan succession in the area indicate that it was deposited during an overall transgression with intermittent changes of sea-level.

Three formations can be distinguished in the Mozaan Group in the Wit Mfolozi inlier (SACS, 1980).

2(b. 1) Mandera Formation ($\pm$ 390 m)

This formation is composed of a basal conglomerate and a quartzitic iron formation unit. The basal conglomerate contains pebbles of vein quartz and quartzite with diameters up to 200 mm, set in a fine-grained quartzitic matrix.

The basal conglomerate is of importance because of its locally auriferous nature, especially at the Denny Dalton Mine. The quartzitic iron formation unit comprises a lower sequence of orthoquartzitic sandstone, followed upwards by green shale and beds of black and red iron formation. The succession is finally capped by an upper sequence of orthoquartzitic to argillaceous sandstones.

2(b. 2) Mpunga Formation (± 590 m)

This Formation consists mainly of dark-grey shale with two or three thin, wedge-shaped quartzite intercalations. Beds of dark shale with light-coloured siltstone laminae are also present.

2(b. 3) Qwasha Formation (> 150 m)

This Formation consists predominantly of ferruginous shale with abundant thin intercalated quartzitic sandstone beds up to 3 m in thickness.

2(c) Lithology and Palaeoenvironmental Interpretation

Von Brunn and Hobday (1976) recognised three distinct lithological units in the Wit Mfolozi section. These are briefly summarised as follows:

Arenite Member: Sandstones of the arenite member are medium to very coarse-grained and consist almost exclusively of quartz. An irregular upward coarsening is accompanied by the progressive intercalation of subordinate congolomeratic lenses which overlie irregular erosion surfaces. An upward gradation from conglomerate to pebbly sandstone is occasionally noted. Subrounded to rounded pebbles of resistant lithology such as quartz, chert, jasper and silicified siltstone predominate. A preferred east-west alignment of long axes was noted. Linear channels up to 2 m deep and 15 m wide occur most abundantly within the upper half of the arenite member. Trough cross-stratification in 10-20 cm thick sets is ubiquitous. Although a general southeastward inclination prevails, various noticeable variations and reversals (herringbone patterns) were found. Ripplemarks and associated cross-laminations occur interspersed with trough-stratification. Within the upper 5 m of the arenite member, there are siltstone drapes and isolated plastically-deformed mudclasts. Above this sandstone containing undisrupted mudstone laminae marks the upward transition into the alternating arenaceous-argillaceous member.

Alternating Arenaceous-Argillaceous Member

In this succession the relative proportion of mudstone to sandstone increases upward. Well-preserved polygonal to branching dessication cracks are present in virtually all the argillaceous interbeds. Mudstone clasts are concentrated in the coarser sandstones. Ripple marks occur in a variety of shapes and sizes and include flat-topped, double-crested, and interference forms. Abrupt changes in dip azimuth are common, suggesting current dispersal at angles of up to 120 degrees.

Argillite Member

The base of the argillite member is marked by a predominance of siltstone and mudstone containing thin, widely-spaced sandstone laminae. Shrinkage cracks are smaller than those noted in the underlying member. Mudclasts occur at the bottom of erosively-based graded units. More frequently the graded beds comprise siltstone containing undulatory lamination merging upward into mudstone. The top few metres of the Argillite member is a homogeneous mudstone with marked ferruginisation towards the top and sporadically graded into jaspellite or haematitic ironstone.

Palaeoenvironmental Interpretation

The contact of the arenite member with the underlying lavas is obscured, but a shallow marine environment is suggested by an association of wave-generated structures. Ripple trends indicate an origin unrelated to processes responsible for the trough cross-stratification. Interference patterns are either produced by wind-induced currents in shallow water or of tidal changes in flow patterns influenced by local topography.

The alternating arenaceous-argillaceous succession is suggestive of intermittent sedimentation and erosion in an environment influenced by periodic traction currents, wave action and sedimentation of fines from suspension. The presence of shrinkage cracks would indiate periodic subaerial emergence. This combination of processes has been documented as especially typical of an intertidal environment.

The argillite member is interpreted as high tidal flat mudflat deposit, an environment where suspension settling was the dominant process. The sequence of textures and structures from the upper part of the arenite member to the top of the argillite member is quite typical of a regressive intertidalite model. According to this model, a large tidal range of some 25 m seems to have been operable during the deposition of the Wit Mfolozi intertidalites. The studies of von Brunn and Hobday (1976) of the four clastic sequences of intertidal origin have yielded tidal range estimates of 25 m, 20 m, and two of 12 m.

A later study of another section of the Wit Mfolozi inlier by von Brunn and Mason (1977) has substantially confirmed the above interpretations.

A further investigation by Dix (1984) of a 250 m thick sequence of Mozaan sediments around the Denny Dalton area suggested that the Mozaan basin-edge trended approximately east-west, with some local variations. He recognised a transgressive sequence, from braided-stream to shelf mudrock and ironstone deposits. Basin regression followed and is indicated by a thick sequence passing up from subtidal to mid-tidal and high-tidal deposits. Dix suggests a provenance area to the south and south-west of Denny Dalton, a finding which is at variance with the northerly source area with a southwesterly sloping platfrom postulated by von Brunn and Hobday (1976) and von Brunn and Mason (1977). These conflicting directions of postulated depositional dip, probably merely reflect local palaeocurrent variability related to an irregular basin margin.

Southern Domain

This domain is essentially centred around the Nkandla area. The area constitutes the type locality of the Nsuze Group, while rocks of the Mozaan Group have been regarded as being absent (du Toit, 1931). Recent field mapping by Mathews (1990), however, has shown the presence of Mozaan Group sediments in a very restricted area referred to as the Mhlatuze composite wedge structure. The position of this wedge is indicated on Map 1.

Until the recent work referred to above, previous work on the Nsuze Group inliers around Nkandla is limited to a few publications and the unpublished mapping of Mathews (1979). The emphasis of these studies was mainly directed at elucidating the regional stratigraphy and structural geology (Mathews, 1959).

A comprehensive mapping programme by Groenewald (1985) attempted to establish the lithostratigraphy, depositional palaeoenvironment, and petrogenesis of the Nsuze Group sediments and volcanics in the southern part of the Pongola basin, to the northwest of Nkandla.

du Toit (1931) proposed a six-fold subdivision of the Nsuze Group into alternating quartzite and volcanic units. An unpublished work by Mathews (1979 cited in SACS 1980) proposed a nine-fold subdivision of the group. The lower five formations correspond to the units of du Toit (1931), whereas the upper four units define a stratigraphy apparently confined and unique to the central Nsuze Syncline. Mathews could not correlate these units beyond the limits of this syncline due to shearing in the anticlines separating it from the adjacent structures.

Nsuze Group - Lithostratigraphy

Establishing a formal lithostratigraphy for the group in this southern domain poses several problems because the area is structurally complex, exhibits considerable lateral variation in thickness and lithology, and the formations are scattered in several discrete inliers. In the area studied by Groenewald (1985), the stratigraphic subdivision cited by SACS (1980) has been used, with the addition of one new formational name. The Nsuze Group as mapped has been subdivided as follows:

(i) Ndikwe Formation: a sequence of intercalated volcaniclastic and epiclastic sediments up to 1 000 m thick, wedging out southwards at the base of the group. According to Groenewald (1985), this formational unit has not previously been recognised. Facies banded iron formation is common in the Ndikwe formation, but virtually absent from the remainder of the Nsuze.

(ii) Mdlelanga Formation: a 1 200 m thick unit of quartz wackes and quartz arenites at the base of the Nsuze Group. Maximum thickness is attained in the south of the study area where it wedges out or interfingers with the Ndikwe Formation to the north.

(iii) Qudeni Formation: a basaltic andesite, andesite and dacite unit overlying the aforementioned formations. It increases in thickness from 50 m in the north to 750 m in the south of the study area.

(iv) Vutshini Formation: an argillaceous and arenaceous sedimentary unit some 1 000 m thick.

(v) Ekombe Formation: (also referred to as the Mankane Formation) is the highest stratigraphic unit of the Nsuze Group, and in the study area comprises at least 60 m of andesitic volcanics.

Following on a comprehensive description of the lithostratigraphic features of the above formations, Groenewald (1985) has demonstrated feasible correlation between formations within the Southern domain as well as those situated in the Northern and Central domains, despite the apparent fact that the sequences in the various outcrop areas of the Nsuze Group differ substantially. He mentions that the proportion of volcanics in the sequence illustrates such variation. In the northern areas mapped by Armstrong (1980), 90% of the Nsuze Group is of volcanic origin, whilst in the Wit Mfolozi and Nkandla areas the proportion of fragmental volcanics in the same areas is 5%, 0% and 22% in the order shown above. Although there is a systematic increase in the volume of sediment in the group southwards, the volcaniclastic content shows no consistent variation.

Nsuze Group - Sedimentology

Groenewald presents a comprehensive description of the sedimentological features characteristic of the study area. The following dominant sedimentary facies are discussed:

. Medium-scale cross-stratified sandstone
. Sandstones with low-angle cross-stratification and horizontal lamination
. Cross-laminated sandstone facies
. Large-scale cross-stratified sandstones
. Heterolithic facies
. Massive, laminated and ferruginous argillite facies
. Banded iron formation
. Conglomerate facies
. Carbonate rocks.

Nsuze Group - Palaeocurrent Data

Groenewald has plotted measured palaeocurrent directions as rose diagrams for each formation and the whole sequence.

Within the Ndikwe Formation trough cross-beds indicate a range between southwest and northwest. The planar foreset measurements were found to indicate a bimodal population with south and southeasterly directions being dominant. Wave ripples exhibit a southeasterly flow direction. These conflicting data suggest mixing of populations from different depositional environments. The common factor in the groups is that south to southeast and west to southwest palaeocurrent directions are most common.

The Mdlelanga Formation trough cross-stratification data are weakly bimodal with south-southeast trends dominant. Planar cross-stratification suggests a generally southwards flow. Wave ripple strikes display a strong northeast-southwest mode, normal to the flow directions indicated by the trough and planar cross-stratification. Measurements for this group are reasonably consistent, indicating a palaeoslope towards the south or southeast.

Data from the Vutshini Formation are much more contradictory.

Groenewald makes the following inferences based on the work in his study area.

The arenaceous and argillaceous sediments can be divided into several facies based on sedimentary structures and petrographic associations. The sequence in which the facies occur allows comparison with established facies models. Groenewald states that the Nsuze Group data suggests a predominantly marine origin for the sedimentation, particularly so in areas where cycles of arenaceous and argillaceous deposits have the characteristics of shoreline, proximal shelf and distal shelf sequences.

The palaeocurrent data is not very useful except that a dominant south to southeast palaeoslope is indicated. Furthermore, the manner in which cycles of shallow and deeper water deposits are in juxtaposition combined with vertical and lateral variation in the sequence indicates a complex tectonic evolution for the depositional basin. Repeated transgression and regression occurred in response to crustal flexing or isostatic adjustment. The occurrence of volcanics at various intervals within the sequence indicates repeated resurgence of magmatism. A feature common to the Vutshini and Mdlelanga Formation is a southward thickening. Whether this thickening represents a shift in the position of the depocentre or continued and progressive uplift of the Nondweni-Nkandla Basement high is conjectural at this stage. Importantly, however, if the basement high uplift was the operative feature, then the study area of Groenewald or in fact the entire Southern Domain may be situated within an embayment or trough, separate from the remainder of the Pongola Supergroup.

Stratigraphic Features of Mhlatuze Composite Wedge and Nsuze Nappe

The work described above deals mostly with the upper five formations of the Nsuze Group in the relatively structurally simple study area of Groenewald (1985). Recent and to date unpublished geological mapping referred to by Mathews (1990), has been confined mostly to the complex structural terrain essentially southward of the mapping by Groenewald referred to above.

During this recent project by Mathews, mapping has revealed a folded unconformity which can be regarded as the stratigraphic boundary between the Nsuze and the overlying Mozaan groups of the Pongola sequence. This unconformity was delineated in the Mhlatuze composite wedge-structure located along part of the northern faulted margin of the southern structural domain (Map 1 and Fig. 9(b)). Recognition of the unconformity allows a distinction to be made between pre- and post-Mozaan deformational events within the southern domain and in addition, it provides important suggestive hints to the possible mechanism involved in the northward tectonic emplacement of the Nsuze Nappe across this region, which comprises part of the southeastern margin of the Kaapvaal Craton.

It is again noted that the Nsuze Group in the southern domain contains repetitive sequences similar in all respects to the previously discussed tidalite deposits within the central and northern domains. However, the relative proportions of mature quartzitic sandstones increases substantially southwards as previously noted by Groenewald (1985). Sediments of this type constitute the Mabaleni, Mome, Dlabe and Mdelanga formations of the Nsuze Group. These units vary in thickness from 870 to 1 700 m in thickness and have been traced laterally for distances of up to 20 km. Apart from the upper and lower contact zones, these formations contain no argillites or other lithologies suggestive of low energy sedimentation. The most common facies is large to medium-scale, low-angle cross-bedding.

Less common features are thin and single layer small-pebble lags, sporadic herring-bone cross-bedding and some ripple marked surfaces. These aspects suggest that the thick Nsuze quartzite formations are most likely accumulations of shallow marine sediments that were influenced by strong tidal currents during deposition across a wide subsiding continental shelf. Subsidence of this shelf was interrupted by spasmodic volcanism which is evidenced by at least four sequences of basaltic, amygdaloidal lavas, 100 m to 600 m thick. The lavas show no evidence of sub-aqueous extrusion, and have sharp basal contacts above a thick sequence of lithologically mature quartz arenites.

The following lithostratigraphic subdivision of the Pongola sequence in the Nkandla area is taken from SACS, 1980:

Nsuze Group	Mankane Fm - Amygdaloidal basaltic lavas	7 200 m
	Vutshini Fm - Quartzites, minor shales and iron formation near base	1 030 m
	Qudeni Fm - Amygdaloidal basalts	580 m
	Mdlelanga Fm - Quartzites	1 475 m
	---------------------- Tectonic contact --------------------	
	Msukane Fm - Phyllites with some intercalated sheared amygdaloidal lavas	1 1 30 m
	Dlabe Fm - Quartzites with amygdaloidal basalt near top	1 510 m
	Mome Fm - Quartzites, with subordinate upper zone of amygdaloidal basalt, phyllite, and iron formation	1 680 m
	Mabeleni Fm - Quartzites, with thin upper zone of phyllite and iron formation	910 m
	Hlathini Fm - Two alternativing quartz-sericite schists and phyllites	300 m

STRUCTURE

Discussion of the main structural features of the Pongola Supergroup will be divided into the same three domains previously outlined, namely the Northern, Central and Southern Structural Domains.

Northern Structural Domain

The three major structural entities comprising this domain are the following:(1) the Pongola-Mozaan basin, (2) the northern disrupted region of this basin which extends across southern Swaziland and (3) the narrow Amsterdam graben, located to the NW of the main basin (Maps 1 and 2). Mention should be made at this point that most of the studies relating to the Pongola Supergroup were essentially aimed at detailed sedimentological aspects of the basin fill as outlined in the section above; little work on the structural aspects, however, was done and reported upon. It is the work of Roering (1968) and Mathews, much of which is unpublished, that provides the best and most concise insight into the structural aspects of the Pongola basin. Much of the following pertinent structural aspects are therefore based on past and recent field work discussed by Mathews (1990).

(1) Pongola-Mozaan Basin

This structure comprising the Hartland and Piensrand basins extends southwards from the Swaziland border for 45 km before it disappears below a cover of flat-lying Karoo strata.

This composite basin represents the maximum regional development of the Pongola Supergroup attaining a thickness of some 13 km. Another notable aspect is the striking asymmetric distribution of the main stratigraphic and structural elements of this basin (Maps 1 and 2). Indicative of this asymmetry is that the Nsuze Group is located almost entirely along the relatively undisturbed western margin of the basin, in contrast to the rest of the basin which contains an extensively deformed assemblage of the Mozaan Group.

The dominantly volcanic Nsuze Group along the present western rim of the Pongola-Mozaan basin rests unconformably on a granite-greenstone basement (Mathews and Scharrer, 1968; Watchorn and Armstrong, 1981) with the volcanics inclined eastwards at 20 to 30 degrees. Apart from this, the Nsuze Group is unaffected by any major tectonics along this rim of the basin. Eastwards, however, towards the centre of the basin, the Nsuze lavas are overlain conformably by the Mozaan sequence. The Mozaan, however, has been deformed into an interlocking mosaic of periclinal structures. These structures are mainly open, oval-shaped or triangular periclines some 10 kms across. These structures are separated either by tight anticlines or major faults. The structure is typical of a type I interference system involving several phases (at least two) of non-coaxial, upright folding.

The F_1 open folds have axial traces trending NW-SE, and the open F_2 cross-folds have axes aligned NE-SW and mainly parallel to the trend of the roughly concordant intrusive contact of the Spekboom granite pluton, which cuts across the eastern sector of the Piensrand basin.

Similar deformation is suggested for two phases of accommodation folding in a narrow NW-SE trending zone ($\pm$ 8 km wide) which flanks the transgressive, intrusive contacts of the extensive Kwetta granite and the small Godlwayo pluton. The existence of these folds is indicated by cross-folding of narrow, well-defined F_2 folds as well as by the folding of associated D_2 thrust-planes.

The concept of the fold processes discussed above, is not directly applicable to the earliest fold deformation within the Pongola-Mozaan basin. It therefore does not provide an explanation for the regional asymmetric structure of the basin. It is likely, however, that the asymmetry must have been an integral element in the earliest structural framework, most likely in the fundamental geometry of the syndepositional basin. It is furthermore conceivable that the early asymmetric framework not only influenced and determined the location and the NW-SE orientation of the earliest phase of folding within the basin, but possibly also influenced the regional distribution pattern of the post-Pongola plutons in this region. In this regard it is of interest to note that von Brunn and Hobday (1976) suggested that the close association of lavas with mature sediments in the Pongola Supergroup was caused by intermittent crustal fracturing. This is furthermore supported by the marked correspondence of a number of elongate Pongola outcrop belts with NW-SE trending linear features which are clearly seen in ERTS satellite images. These appear to be zones of long-persisting structural weakness which were reactivated in post-Pongola times.

(2) <u>Northern Disrupted Region of the Pongola-Mozaan Basin</u>

Extensive remnants of this part of the basin are represented by two narrow belts of Pongola strata (3-12 km wide) trending NNE across southern Swaziland from the southernly main coherent part of the structure.

Structural mapping was carried out by Roering (1968) in a small area in the southwestern portion of Swaziland referred to as the Mahlangatsha Plateau. This mapping identified five distinct ages of deformation S1-S5 in the Pongola supercrustal rocks. The first two periods S1 and S2 are so closely oriented that they can rarely be distinguished from each other. This deformation resulted in folds oriented about north-south trending axes. The main structure mapped by Roering is a syncline which was folded by later S3 deformation with a northeast trend. The S4 phase of deformation did not produce any significant folds, but was responsible for the development of a prominent schistosity dipping 30 degrees to the northwest. Finally the S5 phase of deformation reactivated early bedding planes as thrust surfaces.

According to Mathews (1990), the western or Mahlangatsha belt is separated by some 30 kms from the eastern Kubuta belt of Pongola strata. The separation of the belts is the site of two intrusive granites that form the Hlatikulu pluton and the Nhlangano gneiss domes. Furthermore, Pongola strata along the northeastern margin of the Mahlangatsha belt have been intruded by the Ngwempisi granite. Similar features are noted along the eastern margin of the Kubuta belt, where Pongola beds along consecutive sectors have been intruded by three granites, namely the Kwetta, Mhlosheni and the Mooihoek plutons.

Notwithstanding the extensive disruption of the Pongola strata by the emplacement of these plutons, elements of a stratigraphic framework flanking the northern part of the Pongola-Mozaan basin are preserved. This is evidenced along the western margin of the Mahlangatsha belt where Nsuze volcanics dip eastwards at angles of 30 to 40 degrees away from the granite basement, although the actual contact zone has been obscured by the extensive Usushwana complex. Moreover, the Nsuze volcanics are disconformably overlain by Mozaan sediments, with the Nsuze Group decreasing in thickness northwards along the length of the belt, from 3 km to about 0,5 km at the contact with the intrusive Ngwempisi granite. Such features suggest a wedging out of the volcanic formations against the northeastern margin of the Nsuze depositional basin.

Some 10 km to the east of the Mahlangatsha belt, a segment of the pre-Pongola basement is surrounded on three sides by the intrusive Hlatikulu pluton. The eastern side, however, has been faulted against another segment of the basement that forms the northern flank of the Kubuta belt where it is overlain by southerly dipping Mozaan sediments that locally form the basal portion of the Pongola sequence. This strongly suggests that the Nsuze group has been overlapped from the south.

(3) The Mahamba Fault-belt and Associated Amsterdam Graben

Recent unpublished mapping by Mathews has recognised a major zone of dislocation, the Mahamba fault-belt, consisting of several steeply inclined strike faults that extend NW across the central portion of the Pongola-Mozaan basin. The prolongation of this belt follows the trend of the folded Mozaan formations to the western rim of the basin. At this position the faults splay out to form a complex structural zone some 5 km wide of internal and marginal faults along a fault-bounded belt of Nsuze volcanics. This zone continues in a northwesterly direction and links up along strike with an earlier delineated fault-system (Humphrey and Krige, 1931; Hammerbeck, 1977) which comprises the 20 km wide, Amsterdam synclinal graben located some 80 km from the western margin of the Pongola-Mozaan basin. The Amsterdam graben contains a substantial thickness of Pongola strata (4,7 km).

Most of the faults described above have been intruded by mafic dykes and sheets of the Usushwana complex. These faults include the boundary faults to the Amsterdam graben and the associated northwestern portion of the Mahamba fault-belt.

The presence of Usushwana sills and sheets in the Mozaan formations within the Amsterdam graben, clearly indicates a late to post-Pongola age for this complex. These features not only set an upper age limit for the end of Mozaan sedimentation, but also provides a minimum age for displacements along the Mahamba fault-belt, in as much as intrusive components of the Usushwana complex within the belt are not affected by faulting. As listed elsewhere isotopic dating of of the Complex has yielded a Rb-Sr whole rock isochron age of 2813 ± 30 Ma (Davies et al., 1984), and an internal Sm-Nd isochron age of 2871 ± 30 (Hegner et al., 1984).

Displacements along the central and southeastern portions of the Mahamba fault-belt are suggested by the significant sigmoidal offset pattern of the eastward dipping Pongola sequence that crosses the fault-belt to the southeast of Piet Retief. This structural pattern is explained either as a left-lateral shear displacement of some 35 km within the fault-belt or by the presence of a major monoclinal warp to the northeast with the flexural axis plunging southeast at low angles.

Mathews (1990) points out that in contrast to the Amsterdam graben and the associated northwestern sector of the Mahamba fault-belt, the southeastern sector within the Pongola-Mozaan basin shows no evidence of intrusion by mafic dykes or sheets of the Usushwana complex. This would seem to suggest that the Amsterdam graben conceivably originated as a northeast facing half-graben related to possible monoclinal warping along the Mahamba fault-belt, and subsequently, the opposing flank of the present graben was the result of normal strike faulting along the hinge-line of the half-graben.

Mathews further suggests that the alignment of the fault-belt along the structural keel, and parallel to the early fold-direction within the asymmetric Pongola-Mozaan basin points to a possible genetic connection with the structure of the syndepositional basin.

Central Structural Domain

As stated previously in the section dealing with the Pongola basin fill, the Central domain is exposed within a group of erosional inliers, including the Thaka inliers which were mapped for the first time by Mathews and Silva-Pereira (1978). The domain is characterised by repetitive NW trending outcrops of crystalline basement overlain unconformably by NE dipping Pongola Supergroup strata, a structural pattern that is clearly indicative of extensive block faulting (see Map 1). The typical stratigraphic and structural features of the Central domain of the Supergroup are shown on the cross-section in Fig. 9(a), which is based on data from the Wit Mfolozi and Thaka inliers.

Southern Structural Domain

In contrast to the general N to NW structural trends within the Northern and Central domains, the Southern domain is characterised by E-W trending folds and accompanying zones of thrust-faults. Moreover, geological mapping by Mathews (1979b) has demonstrated an association of thrust-bounded units of Pongola strata that seem to form components of an extensive allochthonous complex. Much of this more recent mapping is an extension of the earlier important structural mapping of the area by Mathews (1959).

Mathews (1990) has utilised the low regional westward plunge of the main Pongola structures within the Southern domain, to construct down-plunge structural profiles as an aid to an analysis and interpretation. The simplified profile shown in Fig. 9(b) extends across the Southern domain and attempts to illustrate the major structural elements of this region. The profile shows the southern domain comprising two contrasting structural units. The upper unit builds the western part of the region, expressed as an extensive, slightly folded allochthonous thrust sheet, the Nsuze Nappe, characterised by a complex internal imbricate structure comprising folded and faulted formations of the Nsuze Group. In contrast, however, the lower unit is an extensive segment of segment of the Pre-Pongola granite-greenstone basement. The basement contains two widely-spaced, E-W trending structural wedges of down-folded and down-faulted Nsuze Group strata which comprise the basal succession of the Pongola sequence in this region. the northernmost down-faulted structure is referred to by Mathews as the Mhlatuze synclinal wedge, and the other down-faulted structure some 20 kms to the south as the Emome synclinal wedge (see Map 1 and Fig. 9(b)).

The northern margin of the Southern domain is sharply defined by an E-W trending system of normal faults, along which both of the above structural units are down-faulted to the south. This fault system is referred to as the Mhlatuze fault-belt.

The southern margin of this domain is characterised by folded formations of the late Archaean Nsuze Group unconformably overlain by southerly dipping strata of the Ntingwe Group. These latter rocks form part of the Natal structural and metamorphic province. Moreover, the Ntingwe sequence is overridden from the south by tectonic slices of metamorphic rocks within the frontal thrust-zone of the ± 1100 Ma Namaqua-Natal mobile belt (Mathews, 1959, 1972, 1981). It follows, therefore, that the tectonic development of the Southern domain of the Pongola Supergroup occurred long before the tectonic evolution of the mobile belt to the south.

From lithological considerations, it may be inferred that the Nsuze Group strata constrained within the Southern domain was subjected to uplift and erosion prior to the onset of Mozaan sedimentation in this region. Furthermore, stratigraphic relationships indicate that the pre-Mozaan erosion surface extended southwards from the pre-Pongola basement across a northward dipping sequence of Nsuze strata, within a half-graben structure with a down-faulted edge aligned E-W along the present trace of the Mhlatuze fault belt (Fig. 10). The thickness of Nsuze strata preserved within this structure is at most 1,5 km. Subsequent folding and faulting of this half-graben and its unconformable cover of Mozaan sediments is responsible for the present asymmetric stratigraphy and structure of the Mhlatuze synclinal wedge (MWS).

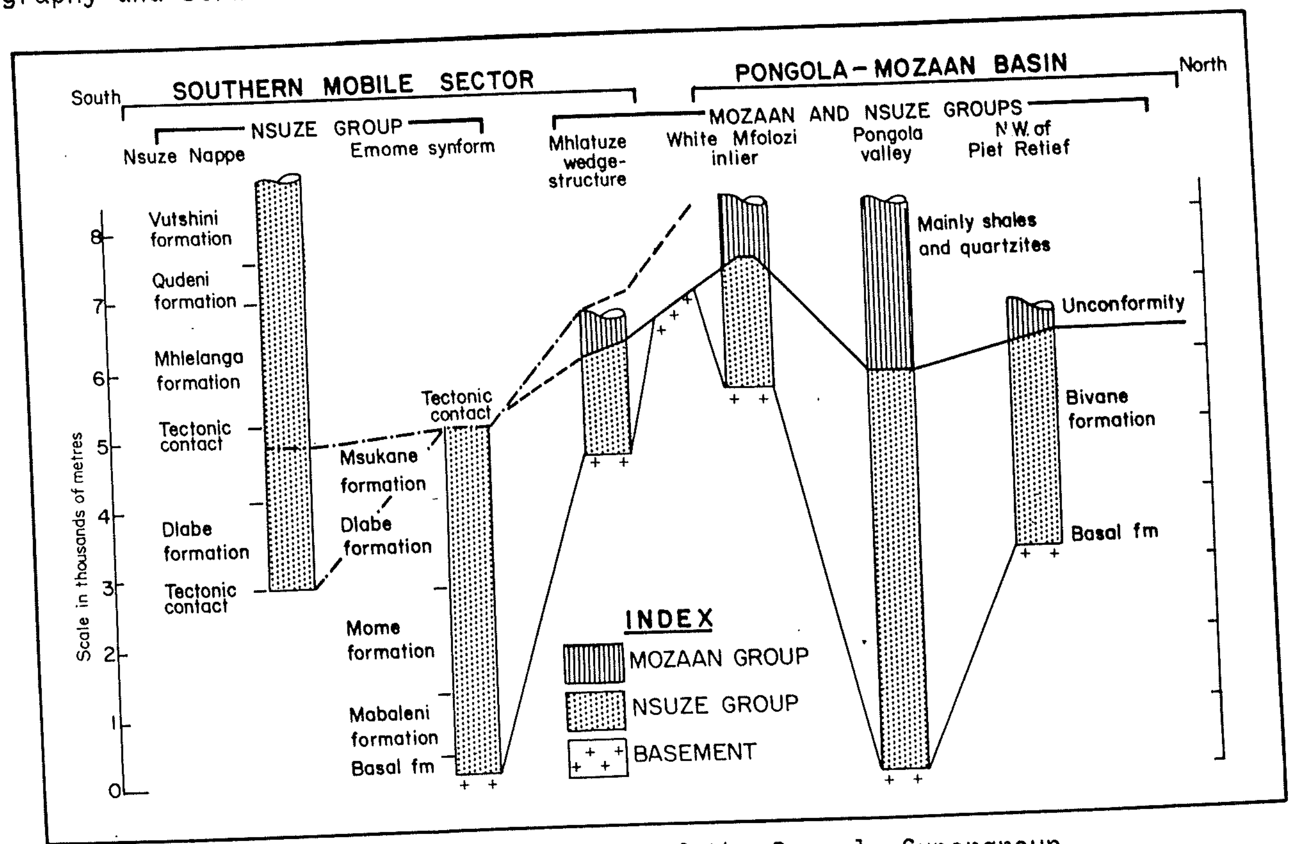

Fig. 10. Stratigraphic sections of the Pongola Supergroup. Simplified after Mathews (1990).

Emome Synclinal Wedge (ES)

This fault-bounded westward plunging synclinal structure is the southern counterpart of the Mhlatuze synclinal wedge. The two structures are some 15 km apart and separated by an extensive body of unfoliated granite (the Nkandla granite) which is part of the pre-Pongola basement.

The Emome synclinal wedge differs structurally from the Mhlatuze wedge in that it lacks the extensive southerly dipping reverse faults. Instead both flanks of the Emome syncline have been down-faulted. Furthermore, a greater thickness of Nsuze group strata, up to 5 km, has been preserved within the syncline (Fig. 10).

It is considered that the Emome synclinal wedge has probably evolved in much the same manner as the Mhlatuze structure, having formed originally as a half-graben with a northward dipping floor (conceivably as a syn-depositional structure) and was subsequently down-folded, and then down-faulted along its southern flank.

Nsuze Nappe

This major allochthonous sheet is the highest preserved structural unit within the southern mobile belt of Pongola Supergroup. The nappe comprises an imbricate system of steep, southerly dipping tectonic slices of folded Nsuze strata with a collective stratigraphic thickness of about 4 kms (Fig. 10). The structural vergence unequivocally indicates northward emplacement of the nappe-complex.

The Nsuze Nappe is expressed at outcrop as a broad, shallow, flat based syncline about 16 kms wide, with a westerly plunge of some 10 to 20 degrees. The basal thrust zone is clearly exposed along the southern flank of the nappe, whilst the northern extension of this thrust below a thin cover of Karoo strata is inferred quite accurately from down-plunge projections, aided by the sharp structural contrast between the intensely folded and faulted Nsuze strata within the nappe and the practically undeformed granitic basement exposed around the eastern margin of the nappe.

The basal thrust along the southern flank of the nappe is readily recognised. It is situated along the contact between a thick northward dipping sequence of quartzites aligned with the trend of the zone. These features can be traced eastwards for some 7 km along strike, and then curve northward around the keel of a broad, westward plunging syncline.

It is clear that the zone of phyllitic schist is a tectonically disrupted and attenuated unit that originally comprised shales with thin quartz arenite interbeds.

A further noteworthy aspect of the zone of phyllitic schists below the Nsuze Nappe is the completely discordant basal contact. This northward dipping contact strikes for a distance of some 7 km obliquely across an underlying, steep southerly dipping assemblage of Nsuze strata (about 3 km thick) within the northern limb of the Emome syncline (Maps 1 and 2 and Fig. 9(b)). It is considered from the above evidence that the contact can be regarded as part of a major, folded post-Nsuze unconformity, and is homologous with the folded unconformity between the Mozaan and the underlying Nsuze sequence within the Mhlatuze structure. It is apparent, therefore, that the basal thrust zone of the Nsuze Nappe was a zone of detachment situated within the basal sequence of the Mozaan Group, near the surface of unconformity with the underlying folded and faulted strata of the Nsuze Group. On the broad scale the relative stratigraphic position of the basal-thrust from south to north can be visualised as follows:

Within the southern sector (which was originally situated a considerable distance to the south of the present limit of the Pongola sequence) the basal-thrust was apparently located along a plane of detachment beneath a 4 km pile of Nsuze strata (Fig. 10). In the central sector, the thrust can be regarded as a structural ramp ascending stratigraphically northwards, at a low angle across a sequence of Nsuze strata to the level of a higher detachment zone in the northern sector. Within this sector (corresponding with the present outcrop area of the Nsuze Nappe) the basal-thrust was situated at or about the surface of unconformity at the base of the Mozaan Group (Fig. 10).

It would seem therefore, that the Nsuze Nappe had a minimum northward displacement of some 20 to 30 kms, from a locality situated to the south of the Emome syncline. It is inferred by Mathews that the northward translation of the frontal portion of the nappe occurred across flat-lying Mozaan strata in an adjacent structural basin. Mathews further proposes that the Nsuze Nappe was emplaced by northward gravitational gliding from a region of uplift which comprised the domain of his postulated miogeosyncline along the southern margin of the Kaapvaal Craton.

BASIN GEOMETRY

Although much of the work directed to the study of the Pongola basin has provided sound models with regard to the depositional environment, little if any attempt has hitherto been made to provide an adequate and acceptable basin-analysis. It is only very recently that Mathews (1990) has attempted a speculative construction of the Nsuze isopach map. The geological parameters from which the isopach data were obtained was essentially based on the following data.

Firstly, it is possible to obtain reasonably accurate estimates of the stratigraphic thickness of the Nsuze Group within the Northern and Central domains of the Pongola Supergroup, since the sequence usually dips at relatively low angles (15 to 35 degrees) and the lower and upper stratigraphic limits are well defined.

Previously presented stratigraphic evidence suggesting a northward overlap relationship involving the Mozaan Group extending across the Nsuze Group, would seem to imply that the northern margin of the Nsuze depositional basin trended NW-SE across southern Swaziland some 15 km west of Kubuta. A gradual thickening persists up to the Mahamba fault-belt, at which point the Nsuze Group attains a thickness of some 2,5 km. However, a marked increase to a maximum thickness of some 8 km occurs within and across the Mahamba fault-belt into the Pongola-Mozaan basin where maximum development of the Nsuze Group has been documented. Geological evidence supports the view that the thickness of the Nsuze Group decreases westwards away from the centre of the basin. This dramatic and abrupt increase in thickness of the Nsuze Group from 2,5 to 8 km westwards across the Mahamba fault-belt lends strong support to the process of syndepositional growth faulting along the trace of the Mahamba fault system, with downthrow to the west. Mathews bases the construction of the isopach map for the Nsuze Group on the above interpretations.

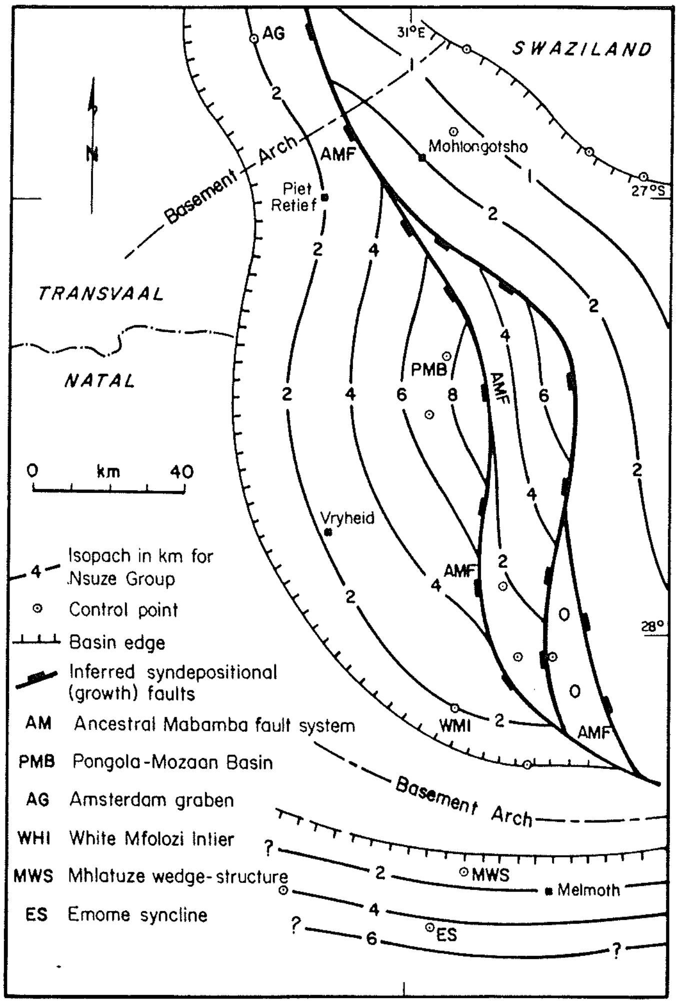

Fig. 11. Isopach map for the Nsuze Group
Simplified from Mathews (1990)

Mathews has extended the above interpretation to the region of the Pongola inliers. Within the Wit Mfolozi inlier, the unconformities that bound the Nsuze Group dip to the NE at divergent angles of 5 to 10 degrees. At constant dips this would imply the Nsuze to have a sub-outcrop thickness of 4 km in a NE downdip direction between the Wit Mfolozi and Thaka inliers. This, however, would imply a sudden decrease in thickness to the NE, based on the evidence of a complete wedging out of the Nsuze Group within the Thaka inlier. This would seem to imply stratigraphic relationships similar in all respects with those in the northern sector, where such relationships have been attributed to pre-Mozaan syn depositional growth faulting with downthrow to the west (See Fig. 11).

Furthermore, the Amsterdam graben (Hammerbeck, 1977) indicates a thickness of some 2 km for the Nsuze associated with this structure. This helps to give some delineation and positioning of the northwestern extremity of the northern domain.

The trends of the isopachs and inferred and related structural features outlined by Mathews strongly suggests that the Nsuze depositional basin evolved as a major half-graben structure, with a floor inclined towards eastern boundary faults. These latter faults acted as syndepositional, growth faults during development of the basin. It is tentatively estimated that the hinge line of this structure, i.e. the western edge of the basin, was positioned about 70 km from the eastern boundary faults; or alternatively, about 35 km from the present western rim of the Pongola-Mozaan basin.

It is possible that the eastern region of the Nsuze depositional basin was situated on part of a stable platform, downwarped slightly westwards towards the fault margin of the half-graben rift. If this interpretation has any real merit, it would be possible for the Nsuze Formations in this region to contain thinned sequences equivalent to major parts of the main Pongola-Mozaan basin succession.

The post-rift subsidence Mozaan depositional basin was deposited within a broad basin which expanded from the axial zone of the Nsuze rift-basin across the margin of this older structure. This evidence is amply supported by the stratigraphic features discussed already.

GEOCHEMISTRY

Geochemical studies of the Pongola Supergroup were undertaken with two specific aims in view. The first of these was to undertake a geochemical investigation of the volcanic rocks to complement the mapping by Armstrong (1980), Armstrong et al. (1982). The results of this work, with special emphasis on the Nsuze lavas between the White and Bivane Rivers is presented by Armstrong, Wilson and Hunter (1986). Additional geochemical data have been presented by Groenewald (1985) for the Nsuze Group northwest of Nkandla and by Preston (1987) with regard to the Mpongoza inlier.

The second type of geochemical investigation was concerned with the geochemistry of Nsuze and Mozaan sediments (with specific emphasis on the pelites) in order to establish the provenance of the Pongola Supergroup, and make tentative comparisons with the older Barberton sediments and the partly synchronous Witwatersrand sediments. Important contributions in this regard were made by Wronkiewicz and Condie (1987; 1989), as well as McLennan and Taylor (1983).

Nsuze Lavas

Area between the White and Bivane Rivers

The lavas in this area display a complete spectrum of chemical compositions ranging from basalt to rhyolite, with the lavas of intermediate composition predominant with ultramafic lavas conspicuously absent. The volcanics are no longer in their pristine state, having been affected by greenschist facies metamorphism. The lavas define a tholeiitic trend on an AFM diagram with the exception of one sample locality which lies in the calc-alkaline field. The predominant tholeiitic character is recognised by the prominent iron enrichment trend, the high and low Ni and Al_2O_3 concentrations respectively, and the variation in TiO_2 contents which reaches a maximum in the intermediate rock compositions.

MgO, CaO, FeO, Al_2O_3, TiO_2, P_2O_5 and MnO show a decrease, whereas SiO_2 and the alkalies increase in concentration from the basic to the acid lava types. Furthermore, no noticeable compositional gaps were observed in passing from the basalts to the rhyolites. The Al_2O_3, total FeO, TiO_2 and P_2O_5 contents all show enrichment trends with peaks in the basaltic andesites and andesites. Trace element variations with rock compositions suggest that Ba, Ce, La, Nb, Zr, Y and Rb increase, and Sr, Cr, Cn, Ni decrease with increasing differentiation.

According to Armstrong, Wilson and Hunter (1986), the significance of the mainly tholeiitic Nsuze volcanics is the evidence that their chemistry bears no similarity to typical Archaean volcanic piles. Although volcanics of tholeiitic affinity are present in Archaean volcanic sequences, the intermediate rocks of acid composition are sparsely developed in contrast to their abundance in the Nsuze lavas.

The compositional continuum from basalt to rhyolite extruded in a continental environment (such as the Nsuze) distinguishes the Nsuze lavas from continental flood basaltic volcanism. The above authors suggest that magmatism associated with rifting is commonly alkaline in character, and that at least some alkali basaltic volcanism is a feature of such tectonic settings. They therefore preclude rifting as a major factor. The writer does not agree with this viewpoint and will deal with this aspect in a later section. What Armstrong, Wilson and Hunter conclude, is that it would seem that the tectonic setting of the Nsuze Group does not find an exact analogue in modern plate tectonic models. With due regard to the fact that the Pongola basin is regarded as one of the oldest preserved cratonic basins, comparisons with modern plate tectonic settings are not considered meaningful.

Area Northwest of Nkandla, Natal

The Nsuze lavas of this area have been investigated by Groenewald (1985). Geochemical data for the Nsuze volcanics within the Nkandla area, plot close to the trends identified by Armstrong (1980), thus suggesting some geochemical similarity between lavas from the Vryheid-Piet Retief area (i.e. area between the White and Bivane rivers), and Groenewald's study area.

The magmatic affinity of the Nsuze Group lavas may be assessed using various geochemical parameters. In a plot of total alkalies-silica diagram, the lavas are classified as sub-alkaline. On the ternary plot of AFM, the plotting of the data overlap both the calc-alkaline and tholeiitic fields. Importantly, if only the unaltered samples are considered, most of the points lie within the calc-alkaline field and well away from the tholeiite trend defined by Armstrong (1980). It would, therefore, suggest that the work of Groenewald (1985) has indicated that the Nsuze lavas from the Nkandla area display characteristics of both tholeiitic and calc-alkalic magma suites. This evidence is not supportive of the conclusions reached by Armstrong, Wilson and Hunter (1986) that the absence of alkali volcanism within the Nsuze precludes rifting as a possible tectonic setting.

Groenewald (1985) has attempted using various discrimination diagrams to aid in the recognition of the tectonic setting. On the whole such attempts have proved disappointing and only one of such diagrams gave some indication of an unequivocal continental volcanic tectonic setting. Similar attempts were made by the writer and in only one instance were acceptable plots concentrated in the field of a continental volcanic setting. It is concluded that such discrimination diagrams are adversely influenced by alteration of the Nsuze lava samples during greenschist facies metamorphism. The evidence for an interplate tectonic setting is therefore tenuous, but is in agreement with Armstrong's conclusions in this regard for the Nsuze volcanics.

Mpongoza Inlier

The geochemical investigations by Preston (1987) of the Mpongoza inlier has found the recognition of chemical characteristics, as also magmatic affinities for volcanic rocks of this inlier to be complex as a result of inconsistencies in the geochemical data ascribed to element redistribution by post emplacement processes.

Variation diagrams to assign magamtic affinities to volcanic rocks are not considered reliable (Preston, 1987) as a result of deuteric and hydrothermal alteration as well as low-grade metamorphism.

Preston found that the AMF diagram of the volcanic rocks of the Mpongoza inlier defines a calc-alkaline trend which is in contrast to the tholeiitic trend for the Nsuze lavas from the study area of Armstrong (1980). This variation is ascribed by Preston to the result of later disturbance of the chemical system. Furthermore, the geochemical data from the inlier does not fit the various discrimination diagrams as already pointed out above.

Although much emphasis is placed on alteration to account for apparent poor fits of the data to the discrimination diagrams, it should be recognised that these schemes of discrimination were devised for Mesozoic volcanics erupted in known plate tectonic settings and may therefore simply be inadequate as role models for volcanic lavas associated with a cratonic basin some 3 000 Ma old, when mantle convection and temperatures must have been completely different.

Nsuze and Mozaan Sediments

It has recently been recognised that terrigenous-clastic sediments provide an important source of information relating to the composition, tectonic setting and evolutionary growth of the early continental crust. The Pongola Supergroup is regarded as one of the oldest and best preserved supracrustal pelite-quartzite successions.

Some of the earlier studies of Pongola pelites reached conclusions that these sediments exhibit compositional characteristics that are intermediate between mafic-rich Archaean and felsic-rich post-Archaean sediments (McLennan and Taylor, 1983; Laskowski and Kroner, 1985).

The above studies have recently been expanded by the work on the geochemistry of sediments from the Pongola Supergroup by Wronkiewicz and Condie (1989). In this latest study a total of 27 Mozaan and 36 Nsuze pelites were selected for chemical analysis. The Nsuze pelites are from four stratogeographic horizons namely the upper Wit-Mfolozi, lower Wit-Mfolozi, Mpongoza and Vutshini River sections. The Mozaan pelites are from the Wit-Mfolozi and Piet Retief areas.

The results may briefly be summed up as follows:

(a) Relative to North American Shale Composite (NASC), most Pongola pelites have similar La/Yb and $Eu/_{Eu}*$ ratios and Large Ion Lithophile Elements (LILE), High Field Strength Elements (HFSE), REE, V and Sc contents.

(b) Ni (300 ppm) and Cr (100-800 ppm) contents are greater than those of the North American Shale Composite, while the Cr/Ni ratios are generally higher than shales and pelites of all ages. These high Ni and Cr concentrations led previous investigators (Laskowski and Kroner, 1985) to conclude that these sediments were derived from sources with substantial mafic or komatiitic components. This interpretation is not supported by NASC-type REE, HFSE and LILE distributions in Pongola pelites. It is now considered more likely that erosion of upper portions of Archaean laterite horizons could account for the high Cr/Ni ratios observed in Pongola pelites.

(c) Local populations of Nsuze pelites, based on major and trace element data, may have resulted from source heterogeneities and/or contemporaneous volcanic input into the basin.

(d) REE, LILE and HFSC contents in pelites suggest that Pongola source rocks were very similar in composition to average Phanerozoic upper-continental crust.

(e) Trace element, geographic and isotopic constraints favour 3,1 Ga hood granites (Lochiel granite) as a major source for Pongola detritus. These granites occur adjacent to and may underlie much of the Pongola basin. Mixing models also indicate that a significant proportion of the Pongola pelites may have been derived from erosion of older basaltic greenstones or Nsuze volcanics.

(f) Geologic, geochemical and petrographic evidence are consistent with Nsuze and Mozaan sediments being deposited in a cratonic basin or intracratonic rift. The presence of arkose, feldspathic sandstone and granite clasts in Pongola sediments favours the rift interpretation. In either case, a craton must have existed in Southern Africa some 3,1 Ga ago.

GEOCHRONOLOGY

Since the early mapping of the Pongola Supergroup by Humphreys in 1913, it has always been tempting to dwell on the close resemblance of the Mozaan to the Witwatersrand Group of sediments. Such resemblance was an important stimulus in the extensive exploration of the Pongola Group sediments in an endeavour to find gold-bearing placers akin to those found in the Upper Witwatersrand Group, if the latter was a possible time equivalent.

Early age datings, however, had always suggested that the Pongola Supergroup was of Archaean age and that the Pongola depository was the oldest epicratonic basin in the world. The work of Allsopp (1964) and Barton et al. (1986) involving whole rock Rb-Sr and Pb-Pb, found that the age of the Witwatersrand sediments bracketed between the basement granitoids forming the floor of the depository and the Ventersdorp lavas overlying the sediments was constrained between approximately 2800 Ma and 2300 Ma. This implied that the Witwatersrand basin was of early-Proterozoic age and that the sedimentation was a response to Proterozoic-style crustal evolution on a stable craton as opposed to the Archaean-style greenstones.

Furthermore, these datings implied that the Witwatersrand Supergroup was considerably younger than the Pongola Supergroup and the important potential economic equivalence of the gold mineralisation faded somewhat into the background. In a recent publication by D.A. Pretorius (1989), much of the important aspects of the Witwatersrand mineralisation is reviewed and the unique nature of the Upper Witwatersrand Group is emphasized. Pretorius particularly emphasizes that the long-held view of Archaean greenstone-granite as sources of detrital gold and uranium has lost favour, mainly because of the fact that even the most productive of the world's greenstone belts falls far short to be considered an adequate source of the prolific quantities of gold in the Upper Witwatersrand Group strata.

Recent work by Robb et al. (1989) to establish an age for the formation of the Witwatersrand Basin, has indicated that the Witwatersrand sediments have been deposited in the approximate timespan between 3060 Ma and 2718 Ma, which is considerably older than the 2800-2300 Ma of previous investigations. This work by Robb et al., places the Witwatersrand into the Archaean era in spite of the evidence that the sedimentation appears to be epicratonic in style.

Further implications of this older age for the Witwatersrand sedimentation is that we are again approaching some "time equivalence" with the Pongola Supergroup dated at between 3028 Ma and 2871 Ma, and the economic potential of the latter for viable gold-placer mineralization has again awakened interest and attendant exploration activities. The overall exploration results described in a later section under "Economic Aspects" have been singularly unsuccessful and it is readily apparent that the Nsuze and Mozaan Group conglomerates of the Pongola Supergroup contain low gold tenor mineralisation quite unlike the rich gold contents of the Upper Witwatersrand Group. In fact the Pongola conglomerates with particular emphasis on the gold content are similar to such placers in the Lower Witwatersrand sediments, and are apparently derived from a greenstone-granite source terrane. In fact, these placers are little different in gold and uranium content to any other placer deposit world-wide derived from similar source terrains.

A seemingly plausible theory proposed by Robb et al. (1989) is based on the existence of extensive, hydrothermally-altered granites found emplaced at the close of the Witwatersrand Basin's history, in a postulated source-area in proximity to the known basin edge. It is furthermore suggested that the intensely-mineralised roof-zones and cupolas of these hydrothermally altered granites (HAGS) were the exogeneous sources of gold and uranium mineralisation. Presumably these granites resembled rich epi-thermal deposits of recent geological time. Pretorius (1989) lists several other potential processes to account for the unique Upper Witwatersrand gold content.

In view of all the above considerations, it is important to establish the geochronological relationships between the Witwatersrand Supergroup and the Pongola Supergroup. In Fig. 12, the most recent and presumably best age estimates for the Pongola Supergroup, Witwatersrand Supergroup, selected "HAGS" and Post-Pongola granites have been plotted. The following pertinent observations arise from a study of the age distributions:

- The Dominion lavas and sediments are not time equivalents of the Nsuze Group lavas and sediments.

- The Kraaipan felsic volcanics are time equivalent to the Dominion lavas, and considering the time-span between the Dominion and the Lower Witwatersrand Group it is now a question of debate as to whether the Dominion Group should be included with the Witwatersrand Supergroup.

- The Nsuze lavas are not time equivalent to the Dominion lavas but are younger by some 50 Ma.

- The Mozaan Group is only partially equivalent to the upper sections of the Lower Witwatersrand Group.

- The Upper Witwatersrand Group clearly post-dates the Pongola Supergroup.

- Some of the "HAGS" cover the time-span of deposition of the Upper Witwatersrand sedimentation.

- Post-Pongola granites, i.e. the Spekboom/Godlwayo and Kwetta granites are of similar age to the "HAGS" referred to above. It is significant that the Spekboom granite is closely related to the gold mineralisation of the Klipwal Mine and its surrounding terrain.

- In the overall context of what we can deduce from Fig. 12, it seems reasonable to state that the Pongola Supergroup volcanism and sedimentation is a distinct and probably unrelated event in terms of Witwatersrand sedimentology though with some degree of time overlap.

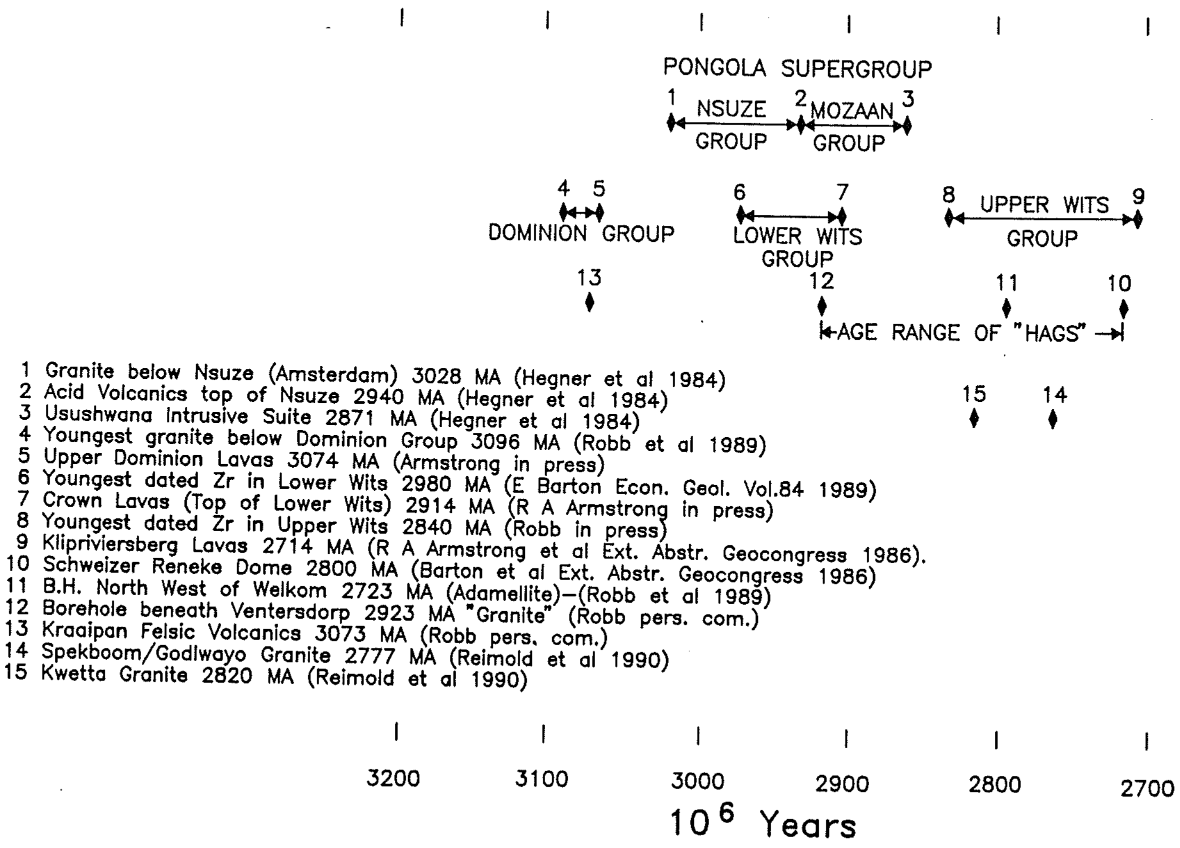

Fig. 12. Plot of Age Datings relevant to the study.

ECONOMIC ASPECTS

Conglomerate Deposits

It should be recognised at the outset that the overall gold potential of the Pongola Supergroup conglomerates is poor. Gold production from the Pongola Supergroup is infinitesimal as compared to the Witwatersrand Supergroup and is at best only about 0,2 per cent of the gold won from the Transvaal Supergroup.

Towards the end of the last century, at several localities, the conglomerates of the Pongola Supergroup attracted a number of prospecting and gold mining ventures, because of their local resemblance to the Witwatersrand gold-bearing conglomerates. Interest, however, ceased by the late-1920s, principally because of the sporadic and low gold content of the mining prospects.

It is noteworthy that sulphide-bearing auriferous conglomerates of the Nsuze Group are only found in the Nkandla region. Further north, in the Wit Mfolozi inlier and in the Piet Retief-Amsterdam area, the sulphide-bearing auriferous Nsuze conglomerates appear to be absent and mineralised conglomerates are confined to the Mozaan Group (Fig. 13).

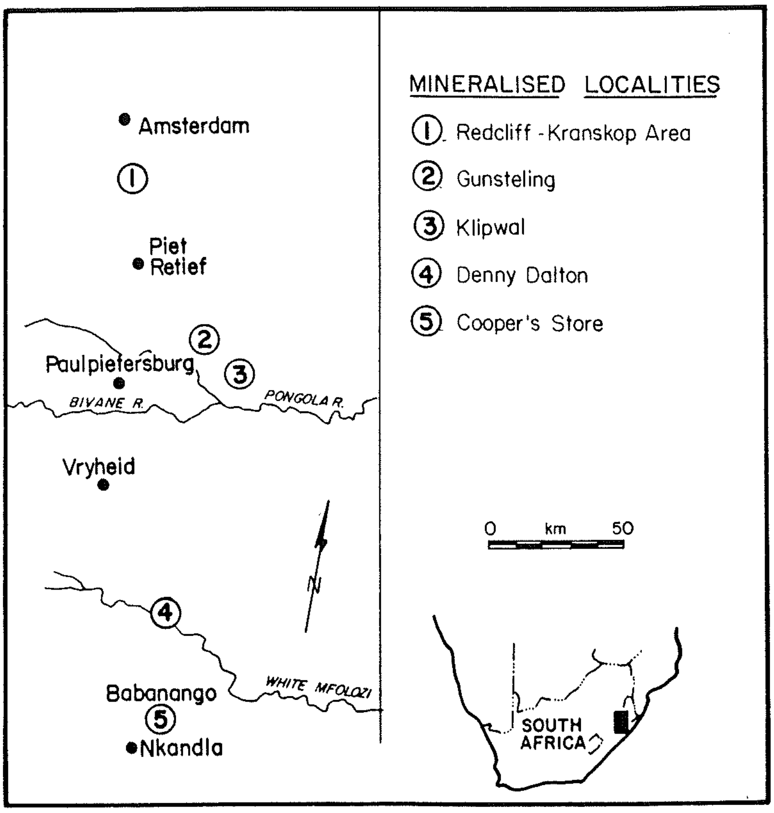

Fig. 13. Map showing distribution of gold deposits.

Since the mid-1960s, several mining companies have resumed exploration within the Pongola basin for viable gold mineralisation within these conglomerates with little if any success. Recently there has been a resurgence of exploration activity in the region, but no details of results have been published.

Nsuze Auriferous Conglomerates

Hatch (1910) briefly described four occurrences of placer gold in conglomerates stated to belong to an arenaceous phase of the Nsuze Group in the Nkandla area. These are briefly described as follows:

The Dickson Mine

This prospect is centred on a thin seam of conglomerate which is one of a series of conglomerate beds which strike east-west and dip at 77 degrees to the north. All of these conglomerates were prospected, but the Dickson reef was the only one which yielded some encouraging results.

The workings consist of trenches and shafts, the deepest of which was sunk to a depth of 30 m. In addition, some 400 tons of material were stoped. Eleven samples taken at 3 m intervals along the floor of the stope averaged 10,3 g/t Au over a width of 21,3 cm equivalent to 219,4 cm.g. These values were not considered viable.

The Speedwell Workings

Located near the village of Ntingwe on the farm Qudeni 25, the conglomerate beds have been evaluated by numerous adits and some vertical shafts over a width of about 80 m and a length of strike of some 300 m. Seven samples rendered gold values ranging from 0,8 to 5,1 g/t Au and averaged 3,1 g/t Au over a sample width of approximately 45 cm.

The Central Nsuze Reef

Situated on the western slope of the Nsuze Valley, the approximately 1 m-wide pyritic conglomerate was prospected over a strike length of 150 m. Five incline shafts and 14 smaller adits bear testimony to the mining operations. The prospect, however, was mined without success by the then Mines Department of the Colony of Natal during the period 1903-1904. Hatch (1910) reports two gold assays of 4,4 and 6,2 g/t Au over widths of 25 and 30 cm respectively.

Cooper's Store or Randalhurst Gold Occurrences (Fig. 13)

This prospect is situated south of the Nkandla-Melmoth road along the Umhlatuzi River. Several sizeable shafts and adits are noted at various places. The gold contents of the reef seem to have been low. Up to 1910, some 105 tons of ore were treated and yielded bullion weighing 287,6 g of gold. du Toit (1931) reported gold production of 5,5 kg and a tenor of 3 g/t Au for the Randalhurst occurrences.

Mozaan Auriferous Conglomerates

Redcliffe-Kranskop Area near Amsterdam (Fig. 13)

This area and those listed below were investigated by Saager et al. (1986) for gold and especially uranium mineralisation. In the Amsterdam area a Mozaan basal conglomerate is situated about 5 m above the Mozaan-Nsuze contact. The conglomerate is matrix supported and poorly sorted and has a polymictic composition. The area has been surficially prospected and fresh sulphide-bearing material has been found in only a few trenches. Although no gold has been reported from the area to date, the conglomerates show distinctly enhanced uranium and thorium contents, ranging from 5 to 34 g/t e U_3O_8 and 5 to 334 g/t e THO_2.

Gunsteling on the North Bank of the Pongola River (Fig. 13)

On the farm Gunsteling 21, some 100 km south-west of Piet Retief, a 7 m-wide conglomerate zone containing a few layers of sulphide minerals occur in quartzites of the Mozaan Group. Four trenches suggest that active gold prospecting was carried out. Although no records of the tenor of the gold mineralisation is available, attention is drawn to the interesting uranium and thorium contents noted in the phyllites underlying the conglomerate and presumably derived from the latter, during recent weathering.

Denny Dalton Mines, Wit Mfolozi Inlier (Fig. 13)

This was the largest placer gold producer in the Pongola Basin. The Denny Dalton Mine is situated within the Wit Mfolozi inlier on the farm Tusschenby 41 (see Fig. 13 and Maps 1 and 2). Various large adits and stopes, driven into the basal conglomerate zone of the Mozaan Group, testify to the relatively extensive mining at this locality.

Detailed sampling carried out by Hatch (1910) revealed that the gold distribution in the Denny Dalton conglomerate is very erratic. Hatch calculated that the gold ore had a tenor of 3,8 g/t. It is suggested, however, from a variety of sources, that we can assume an average grade of about 4 g/t Au for the ore mined at Denny Dalton Mine, where mining was intermittently carried out until 1926. It is probably a fair estimate that about 100 kg of gold bullion was produced in total up to that date.

In 1974 the uraniferous character of the conglomerate at the old workings was confirmed during reconnaissance and a protracted exploration programme was carried out by Southern Sphere Uranium (Pty) Ltd. during the period 1974-1978.

Mineralisation at Denny Dalton occurs in uraniferous and auriferous, pyritic, quartz-pebble conglomerates in the basal formation of the Mozaan Group. These conglomerates extend over a strike length of some 15 km within a topographic feature known as the Wit Mfolozi Inlier.

The principal economic horizon, designated as the Mozaan Contact Reef (MCR), is situated unconformably above the top of the Nsuze Group. Around the environs of the mine the unconformity is characterised by a marked sedimentary overlap. Other conglomerate units situated above the MCR also have some possible potential for economic mineralisation, the most important of which is the Hanging-wall Reef (HWR) which overlies the MCR, and contains some U_3O_8 and Au values.

The Mozaan Contact Reef is economically the most important unit. The MCR is typically a large-pebble ($\pm$ 3 cm), polymictic conglomerate; frequently characterised by buckshot pyrite in the matrix when fresh. The conglomerate consists of rounded to angular clasts of white and black chert, milky and smoky vein quartz, quartzite and minor exotic rock fragments. The matrix is a coarse to medium-grained quartzite which is invaribly pyritic. In well mineralised conglomerate, the gold is concentrated towards the base of the reef, while uranium may be more or less evenly distributed throughout.

The HWR is typically a small to medium pebble conglomerate (less than 3 cm). It is pyritic, polymictic and lithologically similar to the MCR.

Mineralogical analysis of the MCR has identified the following heavy mineral suite:

Gold, Pyrite, Marcasite, Rutile, Zircon, Detrital radioactive grains, Chromite, Monazite, various Sulphides, Tourmaline, Molybdenite, Cassiterite and magnetite.

Evaluation drilling of the Denny Dalton area indicates the potential reserves to total some 235 kg of Au and 40 000 kg U_3O_8 according to calculations made by Southern Sphere Uranium (Pty) Ltd. It would appear from these figures that the deposit is not viable.

Quartz Vein Deposits

Klipwal Mine Figs. 13 and 14)

The most important of the quartz vein deposits is the Klipwal Mine, situated on the farm Klipwall 33, some 80 km southeast of Piet Retief. The mine was first described by Humphrey (Humphrey and Krige, 1931), who recognised two reefs called the Main Reef and the Quartz Reef. These reefs are roughly parallel and separated by a distance of 6 m. The quartz veins have a northerly strike and dip to the east at about 55 degrees. Humphrey states that the Main Reef consists of an impregnated zone of schistose ferruginous character, through which quartz stringers form a fine network of veins. Associated with the reef is a quartzite bar, which carries sporadic gold mineralisation.

Significantly the mine was started in 1898 and has been intermittently in production to the present day. Mining is currently conducted by Lonrho South Africa Ltd. The mine was worked on an organised basis from 1939 to 1944 during which period some 54 000 tons of ore were milled at a grade of 5,1 g/t Au.

The gold mineralisation on Klipwal is confined to Mozaan sediments. At Klipwal the sediments comprise shales, quartzites, and sills of diabase.

In 1945 the mine was investigated by Bewick, Moreing and Company and in the period 1966-1967 by the Anglo American Corporation. Lonrho South Africa Ltd. acquired control of the mine in 1974. These investigations produced the following salient results:

The Bewick Moreing and Company investigation considered the gold lodes to be associated with structures resulting from folding and two types of lodes namely quartz and quartz sulphide bodies, and sulphide impregnations in shale beds or fault zones were recognised. The Company considered that after further exploration of the 5th and 6th levels an estimated 220 000 tons of reserves would be available at a grade of 6,4 g/t Au.

The Anglo American Corporation resampled the 4th and 5th levels of the mine, in addition to surface trenching and drilling. It was generally concluded that structural control of the mineralisation was the major factor influencing the distribution of gold and associated minerals. Much of the ore was associated with shear zones in which the gold mineralisation is associated with quartz, calcite, dolomite and the sulphides pyrite and arsenopyrite. Anglo calculated the ore reserves of the Klipwal Mine at 185 000 tons at 8,6 g/t Au over a width of 132 cm. In addition, the northern extension of the Klipwal shear was explored and a 90 m long payshoot was located by trenching some 150 m north of the last known mineralisation in the mine. This ore was exposed in 5 trenches and the average value on surface was 17,6 g/t Au over a width of 250 cms.

The Klipwal Mine has been continuously worked since 1980. The current average gold output is 15 kg gold per month at an average grade of 3,5 g/t Au (J. Mackay; personal communication).

The Klipwal Mine and surrounding prospects are confined to a highly deformed block of Mozaan sediments flanked by the intrusive Spekboom granite to the east and Nsuze Group volcanics to the west. Structurally the area was deformed in the following stages:

(1) Intrusion of the Spekboom granite resulted in easterly directed stress on the block of Mozaan sediments. The Mozaan sediments, originally occupying a shallow north-south striking syncline with a gentle northerly plunge, buckled under the induced stress and deformed the early syncline into a series of fairly open but tighter synclines separated by highly attenuated and sheared anticlines. These latter fold structures have axial planes trending north-south with variable northerly or southerly plunge as shown in Fig. 14.

(2) As the intrusion of the Spekboom granite intensified, a block of Mozaan Group rocks was also enveloped by the granite from the north and the block was thrust southwards over the underlying earlier structures. This deformation resulted in east-west thrust faulting, wrench faulting and renewed shearing of the tight anticlinal folds.

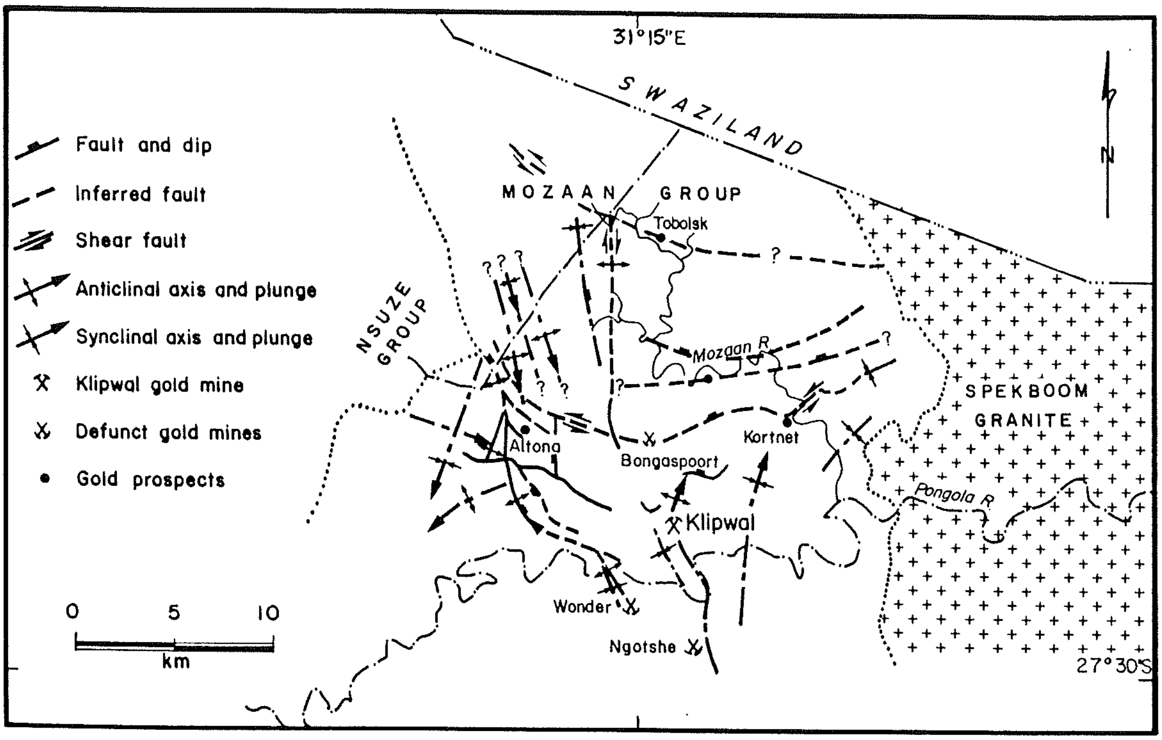

Fig. 14. Main structural features and simplified geology around the Klipwal Mine

The various mines and prospects discussed below may be characterised as having been localised on the following principal structures:

Category A: The Klipwal, Ngotshe and Wonder are associated with fractures and shears situated within the axial planes of attenuated and steeply dipping anticlines. It is likely that the Ngotshe mineralisation is emplaced along the southward prolongation of the Klipwal anticline.

Category B: The Bongaspoort and Kortnek prospects are located on or near an east-west zone of thrusting.

Category C: The Altona and Tobolsk prospects are apparently associated with northwesterly trending shear or wrench faults.

The Wonder Mine and Ross Reef

The Wonder Mine is situated some 5 km southwest of the Klipwal Mine on the Wonderfontein farm, which is ground held by the Natal Parks Board and on which prospecting is not permitted. The gold is found in quartz reefs striking roughly north. The reefs comprise two parallel quartz veins dipping at about 60 degrees. Both these reefs are lenticular with a maximum width of 120 cm and

and have been mined along strike for some 90 m and to a depth of 80 m.

Some 2 km south of the Wonder Mine, the Ross Reef and Wonder extension reefs occur along more or less the same line of strike. Some 13 700 tons of ore were produced from the Wonder and Ross reefs, yielding 128 kg of gold at a recovery grade of 14,9 g/t Au.

The Ngotshe Mine (Vergelegen Mine)

This mine is located on the farm Vergelegen 373 within ground controlled by the Natal Parks Board. Although relatively little is known about the prospect the ore appears to comprise narrow quartz stringers in ferruginous shale. The mine was worked during the period 1951 to 1969. Although much of the work carried out during this period was rather poorly documented and referenced, the vein quartz material shows significant gold mineralisation. Some 110 quartz vein samples were assayed and values ranged from nil to 170 g/t Au. A total of 10 samples of the ferruginous shale were assayed and yielded a range of values from 0,6 g/t Au to 47,5 g/t Au. It is significant that in places the wall rocks are gold-bearing.

Gold Mineralisation on the Farm Kortnek

The farm Kortnek adjoins the eastern boundaries of Bongaspoort and Klipwal farms. It is reported that five mineralised localities occur on Kortnek within a radius of about 1,6 km.

Four of these deposits were investigated by the Bewick and Moreing Company during 1945. These deposits were collectively referred to as the Gorge reefs, stated to comprise flat-lying or gently dipping mineralised shale beds with associated quartz.

A fifth gold prospect on this farm has been referred to as the "Mammoth" Reef. This prospect consists of a quartz, chlorite, sulphide body, dipping to the northwest at 30 degrees and situated between a quartzite footwall and a basalt hangingwall.

The Anglo American Corporation investigated the five gold occurrences on Kortnek and concluded from a brief investigation that only two of the prospects justified further work. On one of those, known as the Donkey prospect, the adit was cleaned out and sampling indicated an average grade of 13,8 g/t Au over a width of 58 cm. The other prospect considered to warrant attention by Anglo American comprises multiple quartz veins located on the axis of an open anticline. The mineralisation in the veins on surface appears to be erratic, but it is reported that 3 out of 9 trenches cut good values ranging from 17 g/t Au over 60 cm to 116 g/t Au over 462 cm. It is reported that the potential strike length of this ore zone is about 300 m.

During Lonrho's investigation of the area, the mineralised veins in trench 9 were explored by seven diamond drill holes at presumably (but unknown) shallow depth. The holes were spaced over a total strike length of 150 metres. Two holes at either end of the strike failed to intersect mineralisation, but the remaining five holes cut values ranging from 1,4 g/t Au over 158 cm to 96,0 g/t Au over 175 cm. It appears therefore that an oreshoot of relatively high grade over a strike extent of 90 metres has been indicated.

Much of the above information relating to the quartz gold vein deposits has mainly been collated from information contained in a report by Southern Sphere Mining and Development Co. (Ltd) (A private company report).

Gold Mineralisation on the Farm Bongaspoort

The farm Bongaspoort 48 HU is located some 67 km east of Piet Retief and north of the Pongola River. Early mining operations on the quartz veins on this farm were intermittently attempted during the period 1918-1922. The farm is currently under investigation by the South African Development Trust Corporation (STK), and the area of the old workings has been mapped and regional mapping of a broad area around the workings was completed. The mineralisation is essentially confined to gold-bearing quartz veins, with associated shearing, faulting and brecciation. The less intense shearing is seen as an important distinction between the gold-bearing quartz veins at this locality and the gold occurrences at the Klipwal Mine. Extensive trench and pit sampling outlined a lens of gold mineralisation within a ferruginized brecciated quartz-shale with quartz veins infilling and accompanying hydrothermal alteration of the mixed breccia and sedimentary host rock. Four infill trenches explored the mineralised mixed zone and the sampling results indicated good but sporadic gold values of up to 16 g/t Au. In order to test the depth potential of this mineralisation four diamond drill holes totalling some 100 metres were completed. The results of these initial holes were poor and the programme was abandoned.

Altona Prospect

The Altona prospect was investigated by Lonrho in recent years. This work included soil sampling, trenching and an 282 m adit. The gold mineralisation at a depth of 30 m was disappointing; a 32 m strike length of mineralisation was proved in structurally disturbed ground which averaged 2,06 g/t Au over a width of 167 cms.

Tobolsk Prospect

No information available.

The structural preparation of the ground for gold mineralisation by the intrusion of the Spekboom granite is the single most important event in the localisation of the Klipwal mine and its neighbouring mineralised prospects. To what extent the granite sourced the mineralised hydrothermal fluids in the gold-bearing structures, or alternatively provided impetus to generate re-mobilization of gold by metamorphism of the Pongola host rocks awaits much additional investigation.

Non Gold Related Deposits

Iron

The shales of the Pongola Supergroup are occasionally ferruginous. Such shales are known to occur in the Paulpietersburg area where they are best developed. The iron content ranges from 29,22 to 25,20 per cent and are too low grade to be economically viable.

Similar and generally lower grade ferruginous shales are present in the Mahlangatsha and Kubuta areas.

Sillimanite

In the Mahlangatsha area the Mozaan Group in part comprises intercalated quartzites and conglomerates. At one locality the quartzite contains two lens shaped zones containing sillimanite as a result of dynamo-thermal metamorphism. No production has ever been attempted from this deposit.

Diaspore-Pyrophyllite

These deposits occur in the Nsuze volcanics in the vicinity of Mozaan and Mtambo in Swaziland. The potential ore zone comprises pyrophyllite, diaspore, andalusite and quartz. Reserves have been estimated at about 240 000 tons.

TECTONIC SETTING OF THE BASIN

It was not until the early 1980's that any significant studies were directed to establish a possible tectonic setting for the Pongola basin. It was pointed out by Bickle and Eriksson (1982) that the Pongola Supergroup could be interpreted as a post-orogenic response to closure of a northward opening passive margin along and within which the Fig Tree and Moodies groups of the Barberton Mountainland were deposited.

As discussed by Bickle and Eriksson (1982) and emphasized by Burke, Kidd and Kusky (1985), the Pongola basin can be explained in terms of a two stage thermotectonic model for the formation of aulocogens or syn-rift depositional basins. In terms of this model, the Nsuze Group reflects the first stage rift-forming event caused by uplift and crustal extension as a result of lithospheric heating. It is furthermore postulated that the Mozaan basin reflects a response to the second event of broad crustal downwarping induced by thermal cooling and contraction.

According to Burke et al. (1985) the characteristics of ancient rifts may be briefly summarised as follows:

(1) Rift deposits not subsequently incorporated in an Atlantic-type continental margin would not (in general) be highly deformed or metamorphosed. This statement needs further consideration and modification in terms of the late post-Pongola tectono-thermal events typical of the main or northern Pongola basin. Much of this post-Pongola event will be discussed in the next section of this review.

(2) Lateral thickness variation can occur over restricted distances

(3) Volcanic and intrusive igneous rocks are frequently bimodal in silica content

(4) Faulted margins and linear rift trends may be present

(5) Subaerial and subaquatic sediments might both be present

(6) A thick, coarse clastic section, often containing volcanics and related intrusives is overlain by a generally thinner, finer sedimentary section usually poor in volcanics.

The overall structural geometry and development described for the northern Pongola basin, are considered in terms of the above criteria to qualify classification as an aulocogen or syn-rift depositional basin. It is further suggested that the first stage rift forming event promoted by uplift and crustal extension was induced by mantle plumes which were active in Archaean times when the mantle was highly convective and presumably considerably hotter than in late-Proterozoic times.

Mathews (1990) suggests that during the initial rift-basin phase, asymmetric subsidence of the rift-floor was easterly towards a syndepositional system of boundary faults of the Mahamba fault-belt type. This episode of rifting was contemporaneous with extensive volcanism which attains a maximum thickness of some 8 km and constitutes the greater part of the Nsuze Group in the northern domain of the basin.

The later thermal-subsidence event induced by a thermal cooling phase of basin development is reflected by a sequence of essentially shallow water tidalite sediments comprising the Mozaan Group. The basin in which these sediments were deposited was relatively shallow, and the sediments expanded from the axial zone of the Nsuze rift basin across the margins of this older structure.

Within the northern sector of the Pongola aulocogen a further episode of tectonothermal activity by either a hot spot or another flare of mantle plume activity caused the following more or less sequential events: (a) Upper Mozaan volcanism; (b) extensive normal faulting; (c) intrusion of the Usushwana igneous complex; and (d) intrusion of post-Pongola granitoids with accompanying complex deformation amd metamorphism within and around the north-eastern part of the Pongola-Mozaan basin. These post-Pongola events will be discussed in the next section of this review.

According to Mathews (1990), the contrasting southern domain comprising essentially quartzites, minor volcanics and clastics was most likely deposited within a slowly subsiding epicratonic basin, to the south of the rift and situated at the southern margin of the Kaapvaal craton. With further regional subsidence and additional accompanying sedimentation, the post-rift thermal-subsidence basin (i.e. the Mozaan Group) of the Pongola aulacogen expanded southwards to coalesce with the Pongola epicratonic basin.

The tectonic deformation of the southern domain has been described in some detail elsewhere, suffice it to state that Mathews (1990) suggests the initial tectono-depositional development and the later deformation of the Pongola Supergroup along the southern margin of the Kaapvaal craton occurred when this sector was located along part of a transform plate boundary with an ocean basin.

<u>"SYN" - POST-PONGOLA INTRUSIVES</u> (excluding Karoo Dolerites)

1. <u>Usushwana Igenous Suite</u>

At the close of Pongola volcanism and sedimentation, mafic and ultramafic magmas were emplaced into the lowest stratigraphic formations of the Nsuze Group. The Usushwana suite of quartz gabbro, diorite, and granophyre was intruded at the interface between the Nsuze Group and the pre-Nsuze granitoid basement to the east and southeast of Piet Retief. A steep northeasterly dip is indicated by the crude layering. However, both gravity and magnetic data seems to suggest that the intrusive suite is dyke-like in character (Hammerbeck, 1982).

Furthermore, Hunter (1970) has suggested that intrusions of the Usushwana complex were emplaced within the Amsterdam graben during a period of reactivated faulting some time after the initial formation of the graben. Within the Piet Retief area, the Usushwana rocks are preserved within a broad zone of re-folding about northwest-trending axial surfaces and dextral wrench faulting.

2. Hlagothi Intrusion

These intrusions are located in the southern structural domain between Nkandla and Babanango, and are confined to the lowermost formations of the Nsuze Group. The intrusions comprise several differentiated sills, each consisting of successive layers of peridotite, pyroxenite, olivine gabbronorite and gabbro. Smaller scale layering of olivine-rich and olivine-poor lithologies are locally present. According to Groenewald (1984), the upper marginal rocks of the sills have skeletal pyroxenes similar to the spinifex textures of extrusive komatiites. The geochemistry of the intrusions suggests that the layering of the sills is the result of successive fractionation of olivine, orthopyroxene and clinopyroxene. The primary magma compositions suggest that they are similar to the komatiitic basalts of the Barberton type. The age of the Hlagothi sills is equivocal, but they certainly pre-date the main penetrative deformation associated with the ± 1 000 Ma-old thrust front.

3. Nhlangano Gneiss Dome

Although it has been generally accepted that the Nhlangano Gneiss of Southern Swaziland was possibly emplaced at the same time as the Lochiel Granite, Barton et al. (1983) defined an Rb/Sr errorchron of 2240 Ma for this unit, which in view of the very high initial $^{87}Sr/^{86}Sr$ ratio of 0,88 implies homogenisation of earlier crustal material. The gneiss dome comprises four elements: (1) a core of Nhlangano Granite Gneiss, (2) the peripherally situated Mahamba gneiss, (3) the Shiselweni amphibolites, and (4) the metasedimentary Mkhondo Valley Metamorphic Suite. The work of Wilson et al (1988), has brought to light three important findings: (1) the Pongola Granite outcrop as originally defined included a distinctive granitoid unit, the Nhlangano Granite Gneiss, which predated the sheet-like batholith constituting the remainder of the outcrop; (2) the Nhlangano Granite gneiss in both its main outcrop at Nhlangano and Nkeweni (some 30 km to the north) has a domal form containing one or more tight synclinal keels of metasupracrustal rocks- and (3) the metasupracrustal near Nhlango can be traced continuously into the Pongola Supergroup outcrop farther to the northwest (See Map 2). These findings suggest that in some areas the Pongola Supergroup accumulated on thermally and structurally unstable crust. This is at variance with the generally accepted belief that the Supergroup was one of the earliest supracrustal successions to have developed on a stable craton. However, this unstable crust does not apply to the homoclinal Pongola outcrop in the southeastern Transvaal. Furthermore, in the Nhlangano area the Pongola Supergroup has undergone interference folding and high-grade metamorphism culminating in granulite facies within the Mkondo Valley Metamorphic Suite. The latter suite comprises mainly quartz-rich metasediments represented by metaquartzite and mica schist with some ferruginous and mafic intercalations. The mafic paragenesis orthopyroxene, clinopyroxene and plagioclase attests to attainment of granulitic facies. Clearly, detailed studies and structural studies, supplemented by geochemistry and age-dating are needed to unravel questions regarding absolute ages and stratigraphic and structural relations between the Mozaan Group, its high grade metamorphic equivalent the Mkhondo Valley Metamorphic Suite and the Mahamba Gneiss and between the Suite and the Nhlangano Granite Gneiss. It is clearly evident that much work remains to unravel the complexities of the Pre?-Syn-Pongola Supergroup metastable sialic crust.

4. Mliba Granodiorite

The Mhliba Granodiorite is geochemically akin to the older granodiorite plutons, but its actual stratigraphic age is unclear.

5. Late Granite Plutons

The third magmatic cycle (Anhaeusser and Robb, 1981) is characterised by the intrusion of discrete granite plutons which frequently show clear cross-cutting relationships to all other Archaean rock types in the region.

These plutons vary in their composition but a number are essentially granitic in composition. According to Robb and Meyer (1991), seven plutons (of which six are shown on Map 1) were emplaced along two subparallel, north-south trending linear belts. The westerly belt comprises the Mbabene, Ngwempisi and Sicunusa plutons, whereas the easterly belt is defined by the Sinceni, Mooihoek and Mhlosheni plutons. The plutons that comprise these two linear arrays are distinct chemically and mineralogically although their bulk compositions are quite similar. It would seem logical, however, to include the Kwetta granite as well as the Godlwayo and Spekboom granite with the easterly belt as indicated on Map 1. These late granite plutons are aged between 2800 Ma and 2500 Ma and therefore appear to be post Pongola (Barton et al., 1983).

As stated by Robb and Meyer, these late granite plutons were emplaced into granites and gneisses representing the first and second magmatic cycles, although the Ngwempisi, Sicunsa, Mooihoek, Mhlosheni, Kwetta?, Godlwayo and Spekboom are known to intrude the volcanic and sedimentary sequences of the Pongola Supergroup. Furthermore, these plutons are typically coarse-grained and may be porphyritic in places. Quartz, microcline and oligoclase are the dominant constituent minerals with subsidiary biotite and occasionally hornblende. The seven plutons studied by Robb and Meyer (1991) are metaluminous to weakly peraluminous granites of a highly differentiated type, with high Rb/Sr and low K/Rb ratios, and strongly fractionated normalized REE traces.

Importantly, these late granite plutons can be subdivided into a high-Ca variety and a low Ca-variety, which seem to equate with I- and S-type granites respectively as indicated on Map 1. The high-Ca plutons are characterised by an accessory mineral assemblage comprising zircon, apatite, allanite and sphene, whereas the low-Ca types contain an entirely different accessory mineral assemblage consisting of "monazite-like" phases, xenotime-apatite and zircon. This can briefly be summarized as folows:

(1) Westerly Belt - high-Ca Granitoids - I-type: Mpangeni (not shown on Map 1), Mbabane, Ngwempesi and Sicunusa plutons

(2) Easterly Belt - low-Ca Granitoids - S-type: Siceni, Mooihoek, Mhlosheni and possibly the Kwetta, Godlwayo and Spekboom granites.

There appears to be considerable uncertainty at present regarding the age, mineralogy and placing of the Kwetta, Godlwayo and Spekboom plutons with regard to the above classification of Robb and Meyer (1991) and much additional research into this aspect is needed. In this regard the work by Mathews (1985) is of considerable significance with regard to these plutons, and is summarized below:

(a) Spekboom Granite and Contact Zone

The Spekboom granite is a light grey homogeneous medium to coarse-grained unfoliated biotite granite. Within a zone of about 400 m from the Spekboom Granite, individual shales and phyllites of the Mozaan sequence show recrystallization to a coarse-grained quartz-muscovite-(biotite) schist containing scattered porphyroblasts of andalusite. It appears therefore that the general assemblages in the Spekboom aureole suggests a medium-grade hornfels facies of metamorphism.

Further evidence of the post-Pongola age of the Spekboom granite was presented in the discussion of the Klipwal gold mine where the important structural deformation and attendant gold mineralisation in the Mozaan sediments was clearly associated with the intrusion of this granite.

(b) Godlwayo Granite

This granite, situated at the northern extremity of the Spekboom granite, is roughly triangular in outline and some 10 km² in total area. The small pluton is a medium- to fine-grained, unfoliated leucogranite.

A completely discordant southwestern margin of the granite extends for 4 km across the structural trend of folded Mozaan strata. The thermal effect of this granite extends to a distance of 1 km from the contact. Outside of this thermal aureole the Mozaan formations and associated metabasic sills and sheets show only low grade regional metamorphism.

Within the inner zone of the aureole, 100 to 500 m from the contact, a variety of tough hornfelsic rocks are developed. The main mineral assemblages are as follows: (1) quartz-muscovite-biotite; (2) quartz-muscovite-cordierite-almandine; (3) quartz-biotite-cordierite-almandine-ferroanthophyllite; (4) quartz-cordierite-almandine-ferrocummingtonite; (5) hornblende-plagioclase-cordierite.

It would seem in general, therefore, that the mineral assemblages in the Godlwayo aureole are indicative of medium grade contact metamorphism.

(c) Kwetta Granite and Contact Zone

This is a megacrystic, pink to grey biotite-hornblende-granite. The megacrysts consist of microcline-microperthite occurring as evenly spaced and randomly oriented crystals up to 8 cm in length. Biotite and hornblende frequently occur as evenly distributed aggregates.

A pegmatitic marginal phase occurs along the southwestern, transgressive contact of this granite with folded Mozaan strata.

Within 200 m of the granite contact, pelitic and semi pelitic units of the folded Mozaan Group have been metamorphosed to tough hornfelses containing quartz-biotite-almandine with some cordierite, and metabasic units are altered to hornblende-plagioclase-hornfels.

It is important to note that superimposed fold patterns in the Mozaan formations along the margins of these three post-Pongola plutons can be regarded as locally developed accommodation structures, which implies that these plutons are anorogenic intrusions.

In conclusion, it should be stressed that both the work of Robb and Meyer (1991) and Mathews (1985) with regard to the late granite plutons point to the need for much additional regional studies. It is considered a possibility that these late plutons were the product of hot-spot trails or mantle plumes which roughly followed a trend indicated by the Mbabane-Kwetta-Spekboom-Hlabisa intrusions. That these late plutons are of economic potential is clearly indicated by the influence of the Spekboom granite on the gold mineralisation at the Klipwal Mine and surrounding prospects.

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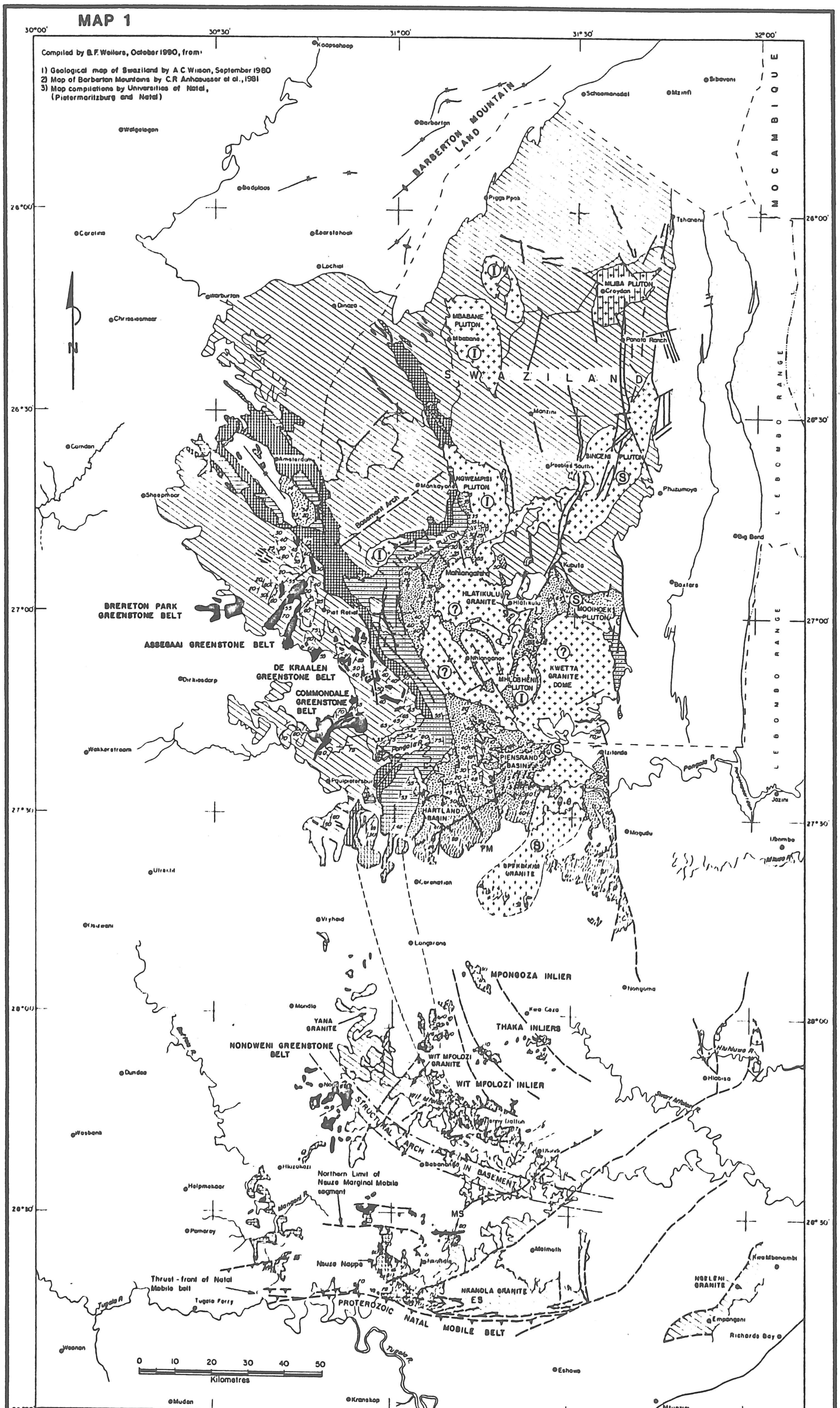
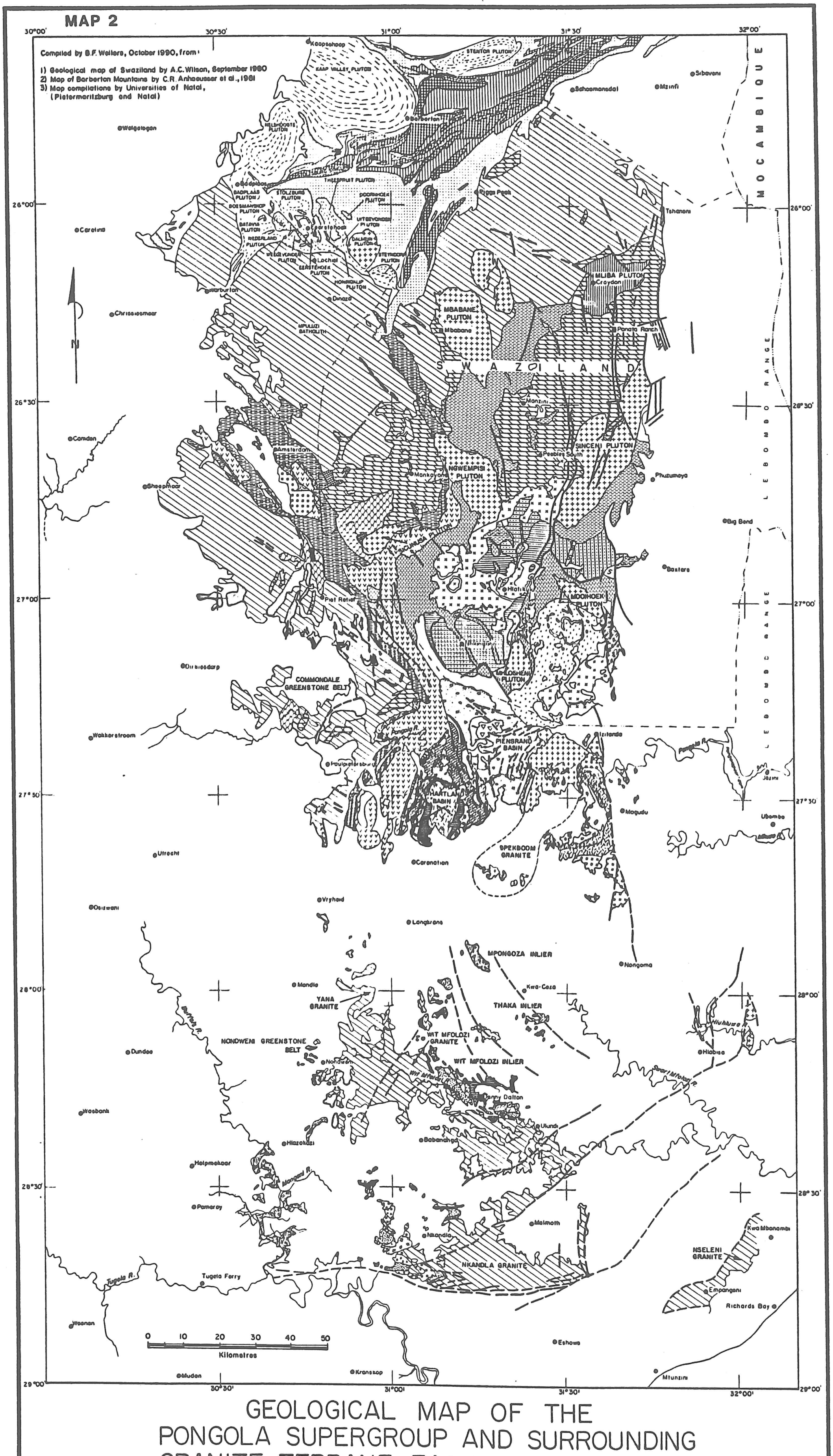


MAP SHOWING DISTRIBUTION, STRUCTURE AND GEOLOGICAL SETTING OF THE PONGOLA SUPERGROUP

LEGEND

- PALAEOZOIC - MESOZOIC COVER
- POST PONGOLA GRANITOIDS "I" and "S" TYPE
- PRE PONGOLA GRANITOIDS
- USUSHWANA COMPLEX } POST PONGOLA ULTRAMAFICS
- HLAGOTHI COMPLEX } MAFIC SUITES
- MOZAAN GROUP } PONGOLA SUPERGROUP
- NSUZE GROUP } PONGOLA SUPERGROUP
- PRE - PONGOLA BASEMENT
- GREENSTONE

- Strike and dip of strata
- Major thrust fault
- FM Major fault
- Shear fault
- Anticlinal axis
- Synclinal axis
- Inferred boundary of sub-outcrop
- International boundary
- FM Mahamba fault belt
- MS Mhlatuze wedge structure
- ES Emome syncline



GEOLOGICAL MAP OF THE PONGOLA SUPERGROUP AND SURROUNDING GRANITE TERRANE, EASTERN TRANSVAAL, SWAZILAND AND NATAL