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THE STRATIGRAPHY OF THE EARLY-PROTEROZOIC BUFFALO SPRINGS GROUP IN THE THABAZIMBI AREA, WEST-CENTRAL TRANSVAAL

by

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ABSTRACT

Outcropping below the Black Reef Quartzite to the west of Thabazimbi, between Sentrum and Ganskuil in the west-central Transvaal, is a succession of early-Proterozoic sediments and volcanics which unconformably rest upon the Archaean granites and greenstone remnants of the Makoppa Dome. This early-Proterozoic volcanic-sedimentary assemblage, for which the name Buffalo Springs Group is proposed, commences with the Hampton Formation, a basal sedimentary unit with a maximum thickness of over 1 200 m, in which braided-stream, meandering-stream, and near-shore sedimentation have been recognized. Overlying the Hampton Formation is the 200 m-thick Waterval Formation, dominantly composed of poorly-exposed basaltic lavas. Conformably succeeding the Waterval Formation is a 850 m-thick heterogeneous pile of altered acid volcanics, pyroclastics, sediments, and basic lavas that constitute the Witfonteinrant Formation. Arenites and wackes of the 40 m-thick Kransberg Quartzite cap the Buffalo Springs Group succession and grade upwards into the base of the Black Reef Quartzite. In view of the gradational contact between the Kransberg Quartzite and the base of the Black Reef Quartzite, the Buffalo Springs Group is assigned to the base of the Transvaal Supergroup and is correlated with the Wolkberg Group that outcrops along the Drakensberg Escarpment in the north-eastern Transvaal.

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I. INTRODUCTION

A. General

Outcropping below the Black Reef Quartzite to the west of Thabazimbi, between Sentrum and Ganskuil in the west-central Transvaal (Figure 1), is an assemblage of early-Proterozoic sediments and acid and basic volcanics, which unconformably overlie the Archaean granites and greenstone remnants of the Makoppa Dome. Previous workers in the region assigned this succession to the Dominion Reef Group (Truter, 1949; Schutte et al., 1960) and to the Ventersdorp Supergroup (Kynaston, 1911; Jansen, 1974). More recently (Tyler, 1978), results of a detailed stratigraphic investigation of the region indicated that the assemblage is conformably overlain by, and exhibits a gradational contact with, the base of the Black Reef Quartzite. In view of these stratigraphic relations, the pre-Black Reef Quartzite sequence between Sentrum and Ganskuil is correlated with the Wolkberg Group of the Transvaal Supergroup. The name Buffalo Springs Group has been proposed for this early-Proterozoic succession of volcanics and sediments (Tyler, 1978).

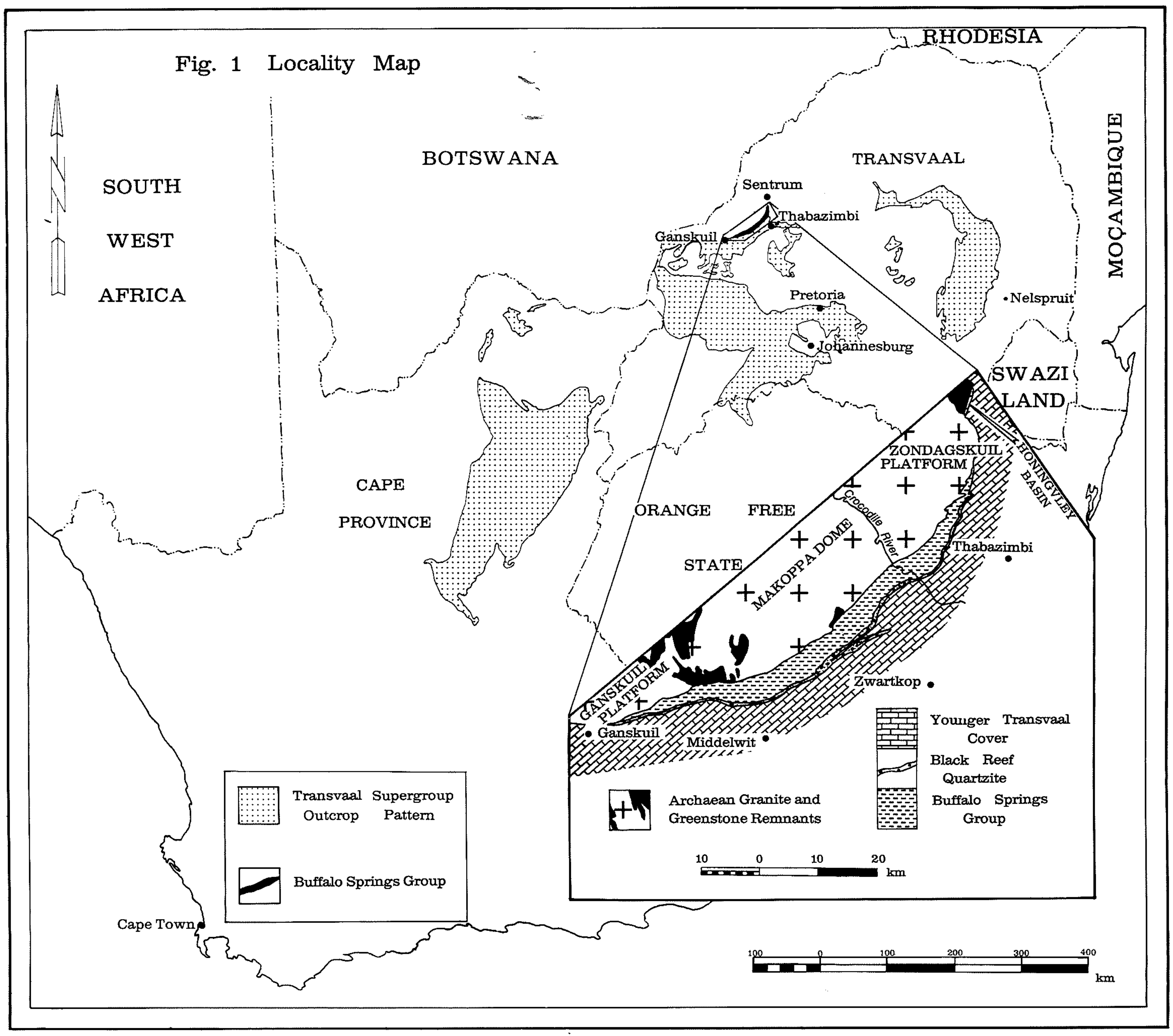


Fig. 1 Locality Map

B. Previous Work

In 1911, Kynaston, recognizing that the pre-Black Reef sequence between the Crocodile and Marico rivers unconformably overlay the "Older Granite" (Makoppa Dome granite), assigned the sediments and volcanics to the Ventersdorp System. Furthermore, he subdivided the assemblage into a lower sedimentary and an upper volcanic unit.

Truter (1949) correlated the succession with the Dominion Reef System, as did Schutte et al., in 1960. Schutte and his co-workers subdivided the post-Makoppa, pre-Black Reef sequence into three suites : a lower sedimentary unit, overlain by basic lava with intercalated sediments and acid lavas, succeeded, in turn, by acid lavas with inter-layered tuff and sediment bands.

Marais (1967) was the first to report on the pre-Black Reef, post-acid volcanic Kransberg quartzite in the Thabazimbi area, correlating the quartzite with the Dominion Reef.

The Geological Survey of South Africa published, in 1974, its 1:250 000 Thabazimbi Sheet, where a return was made to the 1911 classification of Kynaston, in that the succession was correlated with the Ventersdorp Supergroup.

C. Setting of the Buffalo Springs Group

Outcrops of the Buffalo Springs Group are found along a 90 km-long, northeast-southwest-trending outcrop belt, extending from 30 km north of Thabazimbi to the Ganskuil area (Figure 1). The belt varies in width from almost 5 km, in the central positions, to zero, in the vicinity of the Zondagskuil and Ganskuil platforms, respectively (Figure 1).

The basal members of the Hampton Formation of the Buffalo Springs Group unconformably overlie the granitoid rocks and greenstone remnants of the Makoppa Dome. Deposition and preservation of the succession occurred in a 2 000 m-deep trough, bounded to the north and south by basement palaeo-highs. On the northern palaeo-high (the Zondagskuil Platform), a secondary subsiduary basin (the Honingvley Basin) is preserved (Figure 2). This poorly exposed, shallow basin is devoid of volcanic rocks. The major Buffalo Springs depository has a north-south dimension of 80 km, whereas the subsiduary Honingvley basin is only 5 km long and is filled by up to 150 m of sediment.

A number of second-order elements separate the principal tectonic features mentioned above. South of the Zondagskuil Platform, the assemblage thickens into the Mecklenburg Trough, in the vicinity of the farm Mecklenburg 310 KQ. Gentle upwarps (such as the Buffelshoek Arch) are reflected by thinning of the succession. Further south, the Buffalo Springs Group gradually decreases in thickness and finally pinches out over the Ganskuil Platform (Figure 2).

Conformably overlying the upper formation of the Buffalo Springs Group (the Kransberg Quartzite), with a gradational contact, is the laterally-persistent sheet of heterogeneous, clastic sediments that comprises the Black Reef Quartzite in the west-central Transvaal. The Black Reef Quartzite is, in turn, succeeded by the chemical sediments of the Chuniespoort Group (Figure 1), and successively younger cover-rocks of the Transvaal Supergroup.

II. STRATIGRAPHY OF THE BUFFALO SPRINGS GROUP

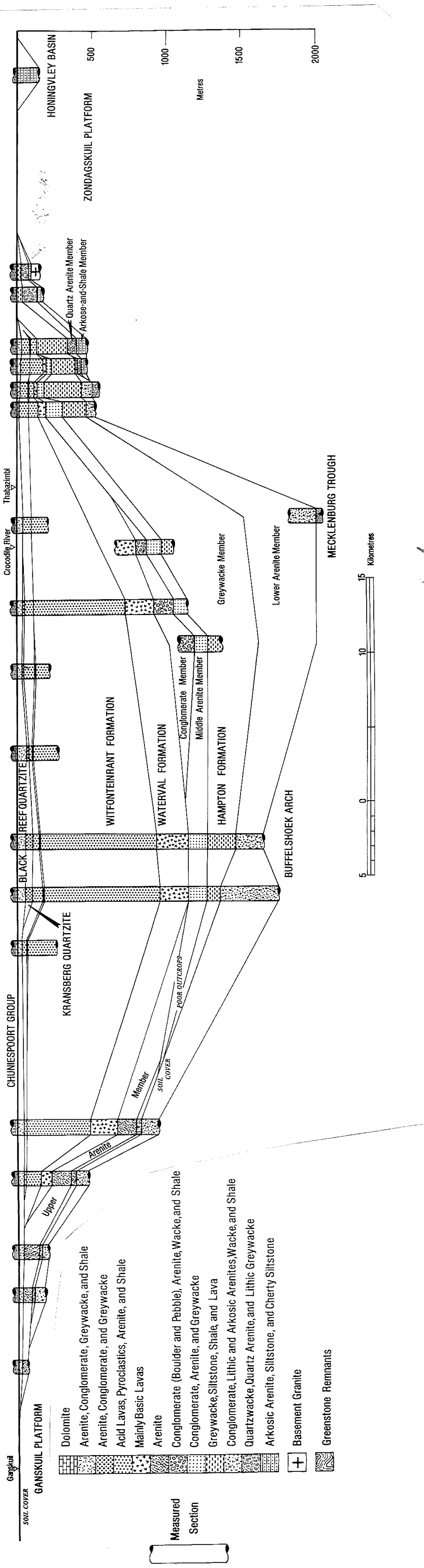
A. Introduction

The Buffalo Springs Group is a heterogeneous pile of acid and basic volcanics and sediments, with a lateral extent of over 90 km. The Group has been divided into three formations which are mappable over a large part of the area. The Hampton Formation (at the base) is largely composed of immature sediments and derives its name from the farm Hampton 320 KQ. The Hampton Formation is overlain by the very-poorly-exposed basic lava unit, for which the name Waterval Formation (from the farm Waterval 337 KQ) has been proposed. The overlying acid volcanics are best exposed along the western slopes of the Witfonteinrant, and this name has been used for the acid volcanics of the Witfonteinrant Formation. Capping the succession is a persistent arenite unit, of formational status, known as the Kransberg Quartzite. This name was first suggested by Marais (1967) and is derived from the farm Kransberg 357 KQ. In addition, a number of units of member status are mappable in the Hampton Formation.

B. The Hampton Formation

Immature, volcaniclastic arenites and greywackes are the dominant constituents of the Hampton Formation. At the base of the succession overlying the Zondagskuil Platform, are two members that are markedly different from the majority of the sediments in the Formation. The basal Arkose-and-Shale Member (Figure 2) is composed of rhythmically-interlayered arkose and shale bands. This sequence grades into a transition-zone and, subsequently, into a mature arenite unit (the Quartz Arenite Member). Overlying the Quartz Arenite Member and developed laterally to it are the immature clastics that comprise the majority of the Hampton Formation sediments. Several members in this sequence of immature rocks have been distinguished on textural and compositional differences. The Lower Arenite Member (Figure 2) is a coarse, dirty unit that is developed at the base and in the central portions of the basin. This unit grades upwards into the fine-grained Greywacke Member, which, in turn, grades into the Middle Arenite Member. The Middle Arenite Member is more mature and coarser than the underlying wackes. An overall upward-coarsening pattern is initiated in the upper parts of the Greywacke Member and continues through to the Conglomerate Member (Figure 2), which is composed of poorly-packed, ill-sorted boulders, cobbles and pebbles. Coarse conglomerates are exposed

Figure 2 : BUFFALO SPRINGS GROUP AND BLACK REEF QUARTZITE
Selected Stratigraphic Profiles



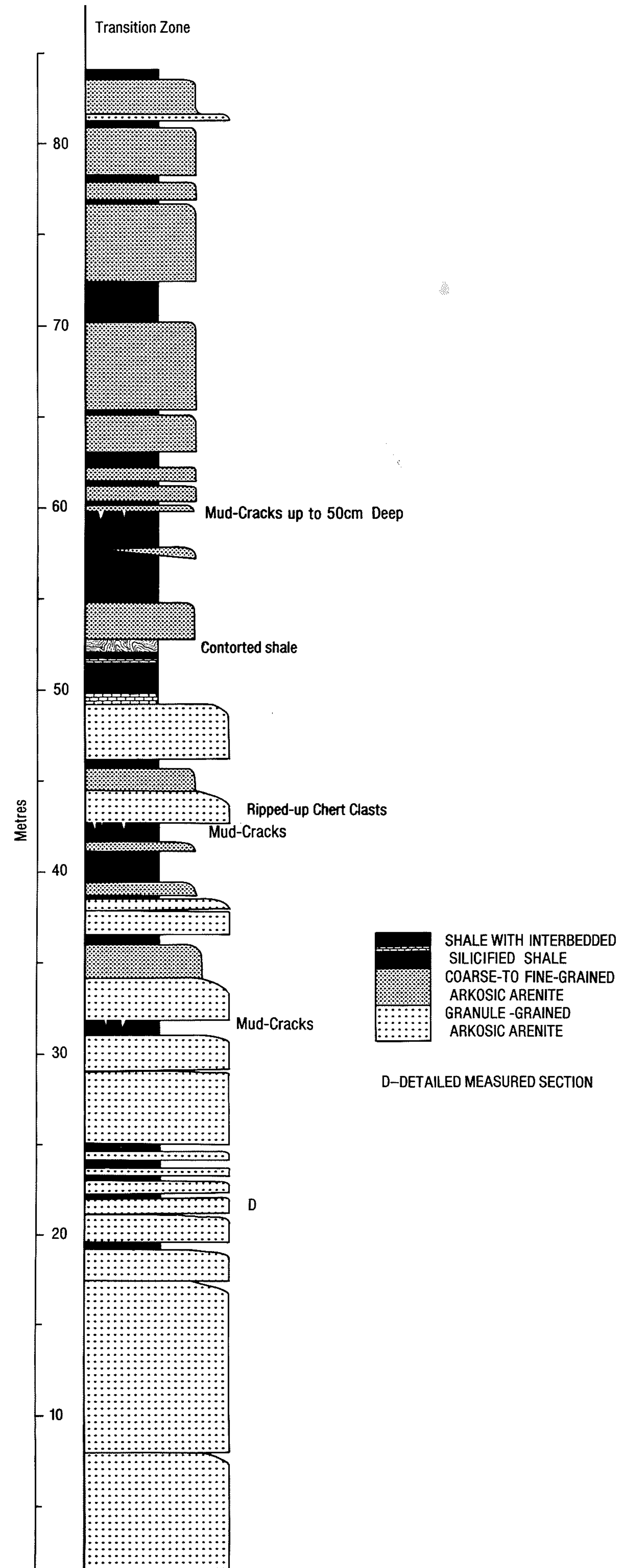


Figure 3 : Detailed measured section through the Arkose-and-Shale Member illustrating the overall pattern of sedimentation (Koedoevlei 128 KQ, Thabazimbi District).

in two lobes, the more southerly of which fines upward into the Upper Arenite Member. This unit may also be present under thick sand-cover in the central parts of the basin.

(i) The Arkose-and-Shale Member

The Arkose-and-Shale Member is well exposed on the western slopes of the Witfonteinrant on the farm Koedoevlei 128 KQ, where the clastics and shale outcrop along a substantial cliff-face. The member is composed of stacked sets of upward-fining cycles which grade from granule conglomerates to thinly-laminated shales. Although the overall pattern is one of upward-fining, each individual cycle is composed of very coarse arkose and thinly-laminated shale in varying amounts. Units of intermediate grain-size in each cycle are minimally developed, that is, the transition from coarse detritus to shale in a bed of 4 m or more may be represented by only 10 cm of fine-grained arkose. However, the boundary between clastic sedimentation and suspension sedimentation is a gradational transition, and not a sharp termination.

Coarse-grained arkosic arenites predominate in the lower parts of the succession (Figure 3). They comprise ill-sorted, angular-to-subrounded, feldspar clasts, varying up to 20 mm in diameter, with finer-grained interstitial quartz, both set in a greenish-brown micaceous matrix. Pyrite crystals up to a centimetre in diameter, altering to hematite, are common. Primary sedimentary structures abound within the arkosic arenites. The base of each arenite band is generally a scour-surface, with scour-and-fill structures varying up to 1 m in depth. Trough-crossbed sets are generally found in the lower parts of the arenite bands and are succeeded by plane beds with occasional troughs. Rip-up clasts of silicified shale are commonly associated with the scour structures. Flute-casts have been noted on the lower surfaces of the coarse clastic layers. The casts comprise elongate, bulbous bodies which flare out towards the southeast, indicating sediment transport in that direction. Palaeocurrent data confirm that the arkosic arenites were deposited by directionally-persistent distributive currents moving from the northwest.

Thinly-laminated shale dominates the finer-grained elements of the Arkose-and-Shale Member. Graded beds, commencing with coarse sand, passing up into silts, are common within the shale bands, as are mud-cracks.

A number of features assist in interpreting the depositional setting of the Arkose-and-Shale Member : the sediments are ill-sorted, coarse-grained and immature; coarse arenites alternate rather abruptly with shale bands; the bases of the coarse detrital bands are scour surfaces which cut into the underlying units; sand-filled mud-cracks (up to 50 cm deep) are common, indicating periodic subaerial exposure and desiccation; and the sequence has a distinct cyclicity, with continuous, near-parallel shale bands alternating with coarse-grained detrital units. These criteria, indicate an environment of limited reworking, influenced by directionally-persistent currents and periodic subaerial exposure. The setting considered most compatible with these features is the fluvial system. Primary sedimentary structures and the abundance of siltstone and shale, which, according to Allen (1965), have a low preservation-potential in the braided-stream system and are poorly represented, suggest that the Arkose-and-Shale Member was deposited in a meandering-stream environment.

(ii) The Quartz Arenite Member

The Quartz Arenite Member of the Hampton Formation is well exposed as cliff-faces on the northern extension of the Witfonteinrant, on the farms Karoobult 126 KQ and Koedoevlei 128 KQ. The gross geometry of the arenite body is lensoid, with a north-northeast, south-southwest strike-length of 6 km and a maximum thickness of over 120 m. From the position of maximum thickness of Karoobult 126 KQ, the unit thins rapidly to the north and to the south where it outcrops as a conspicuous white band, conformably overlying the Arkose-and-Shale Member.

When the Quartz Arenite Member overlies the main mass of the Arkose-and-Shale Member, a 20 m-thick transition-zone, comprising coarse-to-fine-grained arenites, and wackes, is present. This unit is cross-stratified, and heavy mineral layers, composed predominantly of schorl, with accessory rutile, magnetite, and chromite, have been observed. Resting upon the transition-zone, with a thin impersistent basal conglomerate, is the 100 m-thick assemblage of granule gravels, quartz arenites, and quartzwackes that comprise the Quartz Arenite Member.

Light-coloured quartzwackes predominate in the member. Towards the base of the assemblage, the quartzwackes are poorly-sorted and have subangular quartz grains in a sericitic matrix. Upwards in the succession, sorting improves, and grains become well-rounded. Two-to-five cm-thick graded beds, forming horizontally-laminated stacked sets, are common.

A number of quartz arenite bands are present in the Quartz Arenite Member, the most striking of which forms a distinct white band along the cliff-faces of the northern extension of the Witfonteinrant. This quartz arenite band is present along the whole outcrop length of the member, but pinches and swells as it scours into the underlying quartzwacke band (Plate 1a). Grains within this supermature quartz arenite are well-rounded, well-sorted, and well-packed. The most striking primary sedimentary structure within the quartz arenites is the even lamination within 1-3 m sets which are laterally persistent over more than 10 m and which are separated by low-angled discordances (Plate 1b). Other sedimentary structures present are trough- and tabular-crossbeds, graded beds, flat beds, primary current lineations, and interference ripple-marks.

Palaeocurrent work on the Quartz Arenite Member has revealed a bimodal palaeocurrent pattern (Figure 4). Sixty-nine individual foresets were measured at five stations in the member.

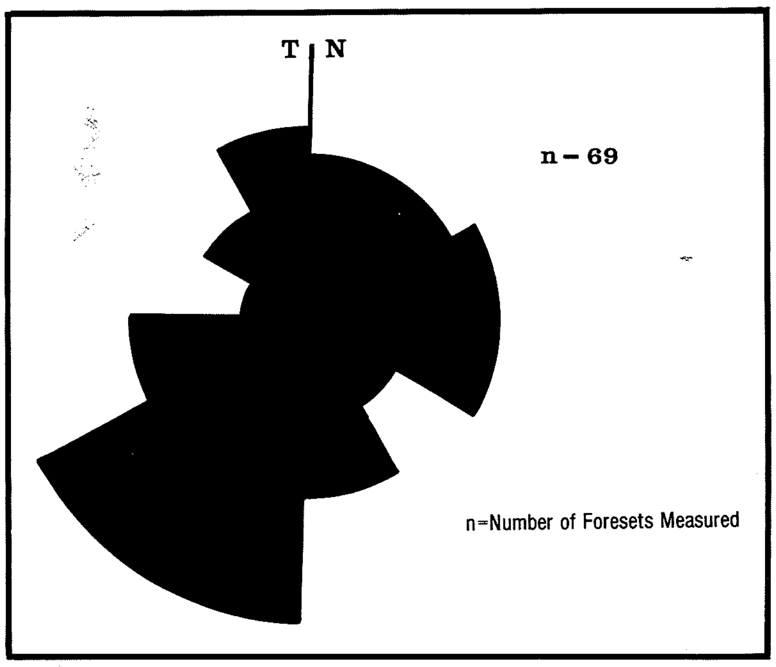


Figure 4 : Rose-diagram illustrating the bimodal palaeocurrent pattern of the Quartz Arenite Member, Hampton Formation.

Preserved within the Quartz Arenite Member are a number of distinct palaeoenvironmental indicators. One of the most important of these is the mineralogy of the detritus which is composed almost solely of quartz grains in a fine-grained, sericite matrix. Less stable components, such as feldspar and volcaniclastics, are present only in accessory amounts, when compared to the total volume of the unit. A second, important indicator is the texture of the quartz grains which are generally well-rounded, a feature commonly associated with high-energy environments or with reworking. The supermature quartz arenite exposed as the white band is composed of extremely-well-rounded and well-sorted grains. The third indicator is the dominance of flat, even, laminae within the member and the presence of inclined, even laminae which are separated by low-angle discordances. Clifton (1969) used the term swash-laminae to describe these structures.

The palaeoenvironment considered most favourable for the formation of the Quartz Arenite Member is the high-energy, near-shore setting. Gently-dipping sets of evenly-laminated sand, showing heavy-mineral concentrations and separated by low-angle discordances, have been documented from many modern foreshore environments (Vos and Hobday, 1977). Other features of the Quartz Arenite Member, which are commonly observed in modern foreshore deposits, include primary current-lineation on laminae surfaces and inverse-textural grading within laminae (Vos and Hobday, 1977). In addition to foreshore sedimentation, other facies of deposition that have been recognized within the near-shore clastics of the Quartz Arenite Member are beach-ridge, and lower- and upper-shoreface sediments (Tyler, 1978).

(iii) The Lower Arenite Member

The Lower Arenite Member unconformably overlies the granitoid rocks and greenstone remnants of the Makoppa Dome, for much of its exposed length (Figure 2). Outcrops of the member may be followed along a strike-length of over 60 km, from the farm Mecklenburg 310 KQ to Holland 237 KP. The northern limit of the body overlies, and interfingers with, the Quartz Arenite Member, whereas, in the south, the unit pinches out over the Ganskuil Platform (Figure 2). Stratigraphically upwards, the Lower Arenite Member becomes progressively finer-grained and exhibits a gradational boundary with the fine-grained greywackes of the overlying Greywacke Member. Figure 2 illustrates how the morphology of the Lower Arenite Member is controlled by the palaeotopography of the granitoid basement and shows the marked thinning of the member over the Buffelshoek Arch. The unit has an estimated, maximum, exposed thickness of almost 500 m in the vicinity of the Crocodile River. The Lower Arenite Member is characterized by immature, poorly-packed, and ill-sorted sediments, with lithologies varying rapidly both with height and along strike.

Lithic and arkosic arenites are the dominant rock-types in the Lower Arenite Member. They range in grain-size from fine sands to coarse sands and granule gravels, often with rounded, quartz pebbles scattered randomly throughout the groundmass. Poorly-packed conglomerate bands are common within the member, particularly in the central and southern parts of the basin. Pebbles are well rounded and generally range up to 10 cm in diameter.

Corase-to-fine-grained, matrix-rich wackes occur either in upward-fining cycles or as fairly persistent units up to 20 m thick. Quartz, rock fragments, and feldspar grains are common constituents of the rock and are generally angular-to-subrounded, poorly-packed, and moderately sorted. Thinly-laminated shale is a common, but minor, facet and is present as thin, impersistent bands which terminate upward-fining graded cycles. Primary sedimentary structures present within the shales and wackes are graded beds, ripple-marks, and mud-cracks.

Bedding features within the Lower Arenite Member are dominated by trough- and tabular-cross-beds. Scour-and-fill structures and stacked sets of ripple-cross-laminated wackes (Plate 1c) are also present. Palaeocurrent measurements on the member indicate that the sands were deposited by directionally persistent distributive currents moving towards the east.

Many of the characteristics of the Lower Arenite Member are common in the overlying members of the Hampton Formation, which are also texturally and compositionally immature. Primary sedimentary structures and the immaturity of the sediments indicate that the arenite members, the Greywacke Member, and the Conglomerate Member of the Hampton Formation were all deposited in a fluvial setting. For this reason, the depositional environments of these members will be jointly discussed, in full, in a later section.

(iv) The Greywacke Member

The Greywacke Member is exposed along a 45 km-long belt of isolated hillocks extending from the southern boundary of Zondagskuil 130 KQ to Kameelpoort 332 KQ. Except for outcrops on the northern extension of Witfonteinrant, exposures are generally poor. The Greywacke Member has gradational boundaries with the underlying Lower Arenite Member and the overlying Middle Arenite Member. In the north, greywackes overlie the Quartz Arenite Member with a fairly sharp contact. Estimates of the maximum thickness of the member are hindered by poor exposure. In the northern part of the study-area, where outcrops of the Greywacke Member are moderate, a maximum exposed thickness of 250 m was recorded. Elsewhere, in areas of poor exposure, this figure may increase to 500 m (see Figure 2). Medium-to-fine-grained dirty sands dominate the lithology of the Greywacke Member. Shales are common, while conglomerates and volcanic rocks are present only to a limited extent.

Fine-to-medium-grained greywackes characterize the unit. Muscovite flakes are commonly observed on bedding planes which are generally even laminae, 1-2 cm thick. The Greywacke Member is composed of stacked sets of graded cycles which fine upwards from a basal, coarse-grained sand that scours into the underlying stratum, through trough- and tabular-crossbedded, medium-grained sands, to planar-bedded, fine-grained sands. Trough- and tabular-crossbeds have low-angled foresets, and the topsets and brink-points of the crossbeds are often preserved (Plate 1d), indicating low-energy depositional currents which were not sufficiently strong to erode the topsets. The graded cycles are often terminated by thin, ripple-marked, silt layers or mud-cracked clay-drapes.

In the northern portions of the area, where the Greywacke Member is directly overlain by the acid volcanics of the Witfonteinrant Formation, a number of pink rhyolite bands are intercalated within the greywackes. Wacke inclusions may be observed at the base of the flows, in which amygdales are often present. Thin, black, amygdaloidal basalt flows are also present.

Palaeocurrent work on the Greywacke Member reveals that the formational currents flowed essentially towards the southeast. However, currents were not directionally persistent, and considerable variations between stations have been recorded.

(v) The Middle Arenite Member

Exposures of the Middle Arenite Member occur along a northeast-southwest-trending, 35 km-long outcrop-belt extending from the farm Koedoevlei 128 KQ in the north, to Buffelshoek 334 KQ in the south. The basal contact of the unit with the Greywacke Member is gradational, whereas the upper contact with the Conglomerate Member is abrupt. However, the Middle Arenite Member is part of a continuing, upward-coarsening trend from the fine-grained sands of the Greywacke Member to the rudites of the Conglomerate Member. Moderate exposures of the member are found in the central portions of the Hampton Formation as isolated hillocks surrounded by bush-covered plains. In the northern parts of the study-area, poor outcrops are found in the valley between the acid volcanics of the Witfonteinrant Formation and the lower sediments of the Hampton Formation. The Middle Arenite Member consists predominantly of poorly-packed conglomerates, coarse-grained, matrix-poor arenites, and fine-grained wackes. It has a fairly uniform thickness of 100-120 m, for most of its strike-length, and thins gradually to both the north and south in the marginal areas of exposure (Figure 2).

Light-brown-weathering arenites, often with hematite-stained cavities containing pyrite remnants, are the characteristic rock-type of the Middle Arenite Member. Varying amounts of feldspars and rock-fragments of volcanic clasts, chert, and quartzite are present in the moderately-mature arenites in which randomly-scattered pebbles are common. Texturally-mature quartz arenites have been observed in the upper reaches of the member and are composed of well-rounded quartz grains, with very little sericitic matrix. Primary sedimentary structures are limited to flat lamination, low-angled, tangential trough-crossbedding, with maximum observed thicknesses of 40 cm, scour-and-fill structures, and upward-fining graded cycles. The finer-grained arenites are dominantly flat-laminated. Trough-crossbeds and scour-and-fill structures are commonly associated with the coarse-grained arenites, near the bases of the upward-fining, graded cycles.

The directions of palaeocurrent flow vary markedly from station to station. Directionally-impersistent currents moved essentially from the north during the formation of the Middle Arenite Member.

(vi) The Conglomerate Member

The Conglomerate Member is exposed in two lobes - a northern one which extends from Hampton 320 KQ to Elandsfontein 335 KQ, over a strike-length of 18 km, and a southern body which extends from Rhenosterkop 351 KP to Holland 237 KQ, a distance of 14,5 km. Rudites of the northern lobe conformably overlie the arenites of the Middle Arenite Member. The upper contact of the unit with the basalts of the Waterval Formation is hidden by thick soil-cover. Conglomerates of the southern lobe have a gradational contact with the underlying Lower Arenite Member in the south (Figure 2). The northern limits of the southern lobe are poorly exposed, but the Conglomerate Member is thought to overlie the Middle Arenite Member. Exposures of both lobes of the Conglomerate Member are restricted to the dip-slopes of isolated hillocks. Areas separating the hillocks are sand-covered, and the underlying succession is poorly exposed. The northern lobe is thicker than the southern lobe, and measured traverses reveal thicknesses of over 80 m. This estimate may rise to 140 m in areas of poor exposure. The southern lobe has a maximum thickness of 35 m. The Conglomerate Member consists of cobble-and-pebble conglomerates, coarse-grained arenites, and accessory wackes and shales.

The gathering of directional data in the Conglomerate Member was extremely difficult due to the fact that the member, in general, outcrops on the dip-slopes of the Middle Arenite Member, and because it generally outcrops as massive conglomerates. Some of the interbedded arenites are trough-crossbedded, but directional data derived from these units have low consistency-ratios and were, therefore, not considered valid.

(vii) The Upper Arenite Member

The Upper Arenite Member may be traced from Langverwacht 235 KP to Jakhalskraal 230 KP, along a strike-length of 21 km. For most of its exposed length, the unit overlies the southern lobe of the Conglomerate Member, but, in the far south, it overlaps the conglomerates and rests unconformably upon the granitoid rocks and greenstone remnants of the Makoppa Dome, on the Ganskuil Platform (Figure 2). The upper contact of the unit is exposed only in the southern parts of the area, where the Upper Arenite Member is overlain by the Black Reef Quartzite. Elsewhere, soil-cover conceals the overlying units of the Buffalo Springs Group. As the upper contacts of the unit are concealed, thickness estimates are extremely difficult. Measured sections reveal thicknesses of up to 40 m; this figure possibly increases to 100 m in areas of poor exposure. The Upper Arenite Member outcrops on the dip-slopes of the range of hills immediately east of Ganskuil.

Light-reddish-brown-weathering arenite is the sole rock-type developed in the Upper Arenite Member of the Hampton Formation. The arenites are dominantly medium-grained, although upward-fining cycles from granule gravels to fine-grained sands, over 10-20 cm, are common. Rounded pebbles are randomly scattered throughout the arenites. In thin-section, the grains are well-rounded, but poorly-sorted, and are mainly composed of quartz, with accessory rock-fragments. The matrix is sericitic, with occasional sericitized feldspars.

Primary sedimentary structures are abundant in the Upper Arenite Member. The unit is commonly flat-bedded, with laminae varying in thickness between 1 and 3 cm. Mega-ripples, with amplitudes of 10 cm and wave-lengths of up to 1 m, are common and often have superimposed, undulatory, small ripples striking at right-angles to the strike of the mega-ripples. Large, flat pavements are covered by small, asymmetrical current-ripples. Trough- and tabular-crossbeds are common, with maximum observed thicknesses of up to 30 cm.

A small amount of palaeocurrent work on the tabular-crossbedded units from one station revealed a weakly-bimodal current pattern, with the majority of foresets being inclined towards the provenance-area in the west and others towards the northeast and southeast (Figure 5).

(viii) The Depositional Setting of the Lower Arenite, Greywacke, Middle Arenite, Conglomerate, and Upper Arenite Members, Hampton Formation

The members of the Hampton Formation, other than the Arkose-and-Shale and Quartz Arenite members, have many characteristics in common. The sediments are texturally and compositionally immature. Poorly-sorted conglomerates are present in all but the Upper Arenite Member, which, however, has pebbles scattered throughout the rock. Although there is some variation in average grain-size, the members consist predominantly of coarse-grained sands in upward-fining, graded cycles. Mud-cracked siltstones and shales commonly terminate the cycles and are scoured into by the subsequent influx of conglomerate and coarse sand. Mud-cracks indicate periods of sub-aerial exposure and desiccation. Similarities in the lithologies of the various units of the Hampton Formation are enhanced by comparable, primary, sedimentary structures. Trough- and tabular-crossbeds, scour-and-fill structures, upward-fining, graded cycles and beds, ripple-cross-lamination, ripple-marked surfaces, and mud-cracks are commonly observed.

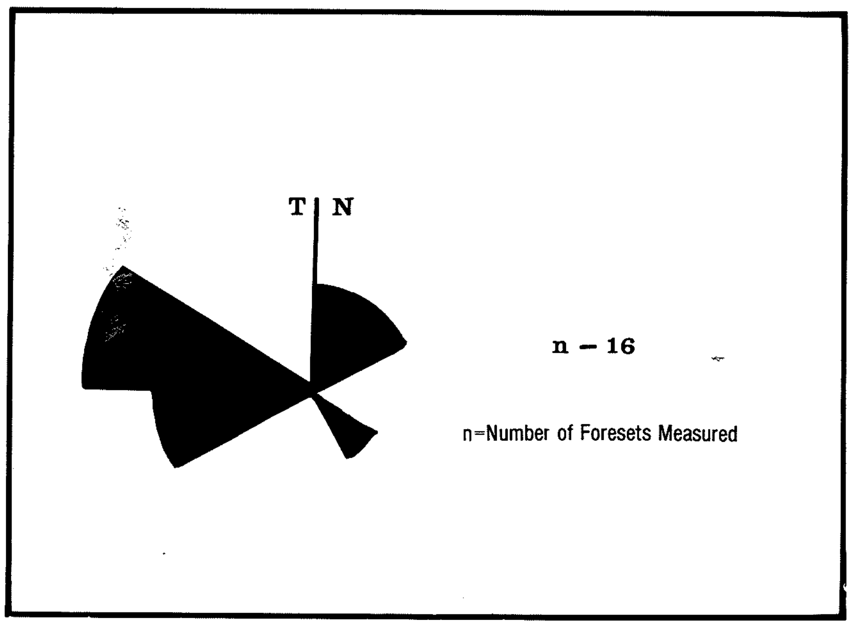


Figure 5 : Rose-diagram illustrating the bimodal or weakly-trimodal palaeocurrent pattern of the Upper Arenite Member, Hampton Formation.

Consideration of the lithologies and sedimentary structures preserved within the assemblage indicate that deposition of the sediments occurred in an environment of limited reworking and periodic sub-aerial exposure. Waning current-strengths caused the release of successively finer-grained particles, until silts and clays were deposited from standing bodies of water to form the upward-fining, graded cycles. The characteristics of the upper sediments of the Hampton Formation are interpreted as most compatible with deposition in a fluvial setting. As these sediments have little shaly material which, according to Allen (1965), has a low preservation-potential in braided streams, the fluvial system considered most favourable for the formation of these sediments is the braided-fluvial setting.

C. The Waterval Formation

(i) Description of Rock Types

The term Waterval Formation refers to the poorly-exposed, basaltic volcanics which rest on the sediments of the Hampton Formation and are overlain by the acid volcanics of the Witfonteinrant Formation. Only two exposures of the easily-weathered, basic volcanics were observed in the north-south-trending valley which separates the basal sediments from the upper acid volcanics of the Buffalo Springs Group. The Waterval Formation derives its name from the farm Waterval 337 KQ, where the best outcrops of basalt were observed. Fresh samples of the volcanics were obtained from a pit on the farm Kransberg 357 KQ.

Outcrops of the unit in the Crocodile River, on the farm Nooigedacht 338 KQ and on Waterval 337 KQ, are composed of dark green-to-black basalts which, on weathering, are internally light-green, but have dark weathered surfaces. When weathered, the basalt is soft and degenerates into a dark-brown soil. Some bands are amygdaloidal, with rounded chert and calcite amygdales. In thin-section, the basalts are intergranular-textured and consist of plagioclase (labradorite), clinopyroxene, and opaque ore minerals. Apatite, calcite, and chlorite are common accessories. The feldspars are usually altered to clay minerals, with the mafic granules being interstitial to the altered labradorite laths. On Waterval 337 KQ, intercalated bands of light-coloured, acid felsites are present within the basalts and stand out in positive relief, as they are more resistant to weathering than the basalts. Also present is a thin agglomerate band, with fragments of acid volcanics and arenite cemented in a basaltic matrix. The arenite clasts are thought to have been derived from the underlying Hampton Formation.

Due to the very poor exposure, mapping of the contacts of the Waterval Formation was difficult. The valley of dark-brown-coloured soils, thought to be underlain by basaltic rocks, extends from Rotterdam 312 KQ to Buffelsfontein 360 KQ, over a distance of approximately 40 km. Thickness estimates are also hampered by poor exposure, but the basalts of the Waterval Formation may be as much as 200 m thick in the central portions of the Buffalo Springs Group.

(ii) Geochemistry of the Waterval Formation

Selection of samples suitable for analysis in the very-poorly-exposed Waterval Formation presented severe problems. Two samples were collected, one from the farm Waterval 337 KQ and the second from a pit on Kransberg 357 KQ. The samples analyzed were amygdale-free basalt. The results are shown in Table 1.

Major-element characteristics of the two samples are markedly different. Sample N.G.D.1 (Table 1, Column 1) had an extremely high loss-on-ignition (LOI) (12,21 per cent) and was found to be

TABLE 1

Major-Element Geochemistry of Basalts from the Waterval Formation, Buffalo Springs Group, Together with Selected Comparative Analyses of Tholeiites and Andesitic-Basalts

	1	2	3	4
	N.G.D.1*	Thaba 108B*		
SiO_2	54,32	52,29	51,50	100,54
TiO_2	0,69	1,80	1,20	1,07
Al_2O_3	6,21	13,73	16,30	14,69
Total Iron as Fe_2O_3	9,07	14,45	10,70	11,30
MnO	0,25	0,17	0,17	0,13
MgO	10,43	4,01	5,90	3,67
CaO	6,92	6,82	9,80	7,08
Na_2O	0,47	1,91	2,50	2,74
K_2O	0,02	2,39	0,86	2,04
P_2O_5	0,10	0,37	0,21	0,14
LOI	12,21	1,29	0,81	1,59
Total	100,69	99,23	99,95	100,54

* Analyst - N. Tyler

1. Waterval Formation basalt, Waterval 337 KQ, Thabazimbi District.
2. Waterval Formation basalt, Kransberg 357 KQ, Thabazimbi District.
3. Average continental tholeiite (Manson, 1968, p. 223).
4. Average composition of Ventersdorp Supergroup andesitic basalts from west-central Transvaal (Tyler, 1978, Table 9, Column 4).

severely carbonated. Sample 108B, from the farm Kransberg 357 KQ, had a chemistry similar to that of continental tholeiite (Table 1, Column 3). The Thabazimbi Sheet (1974) of the Geological Survey classified the lavas as andesites and correlated them with the Ventersdorp Supergroup. Results of this study show that the lavas clearly do not fit Chayes's (1969) definition of andesites which have high SiO_2 contents (58-60 per cent), high Al_2O_3 contents (17 per cent), and a low MgO content (3 per cent). Both analyses (Table 1, Columns 1 and 2) are more compatible with the average composition of continental tholeiite, but are anomalous in that they have low Al_2O_3-contents, which, according to Button (1973), is a fingerprint of the metabasaltic rocks in the Archaean and Proterozoic of South Africa. The basalts of the Waterval Formation have a composition markedly different from the average composition of Ventersdorp basic lava (Table 1, Column 4) which is more andesitic in nature, with a greater silica and alumina content.

D. The Witfonteinrant Formation

(i) Description of Rock-Types

The acid volcanics of the Witfonteinrant Formation are well exposed along the western slopes of the Witfonteinrant, the range from which the formation derives its name. Conformably overlying the acid volcanics, for part of its length, is the Kransberg Quartzite, the uppermost member of the Buffalo Springs Group. Elsewhere, the Black Reef Quartzite overlies the Witfonteinrant Formation which, in turn, succeeds the basalts of the Waterval Formation. In the far northern parts of the area, the acid volcanics overlap the Waterval Formation and rest directly on the Greywacke Member of the Hampton Formation (Figure 2). Exposure of the unit occurs along an essentially northeast-southwest-trending belt, 60 km long, extending from Koedoevlei 128 KQ to Rhenosterkop 251 KP. The Witfonteinrant Formation has a maximum thickness of 850 m in the central portions of the Buffalo Springs Group.

Dark-coloured felsites dominate the lithology of the Witfonteinrant Formation. Pink rhyolites, quartz and feldspar porphyries, variolitic lavas, basalts, various breccias, and intercalated sediments are present in varying amounts. Stromatolitic chert was observed on the farm Nooitgedacht 338 KQ.

Dark-brown-weathering felsites are most common in the central portions of the Witfonteinrant Formation. They are generally massive rocks, with small (up to 3 mm), randomly-scattered, angular white feldspar laths. When weathered, thin parallel laminations may be present, giving the rock a bedded appearance.

Microscopic investigation shows that the felsitic-textured groundmass is composed of quartz, sericitized feldspars, and greenish-brown biotite which is evenly dispersed throughout the matrix but increases rapidly in close proximity to the phenocrysts. Biotite also occurs in coarse clusters. Opaque ore minerals are present in varying amounts, generally associated with biotite. Accessory minerals are sphene, zircon, often with pleochroic metamict halos, chlorite, and epidote. Calcite occurs either as long needles, often closely associated with epidote, or as biotite-mantled amygdales. The phenocrysts vary between euhedral and rounded and are occasionally partially resorbed by the groundmass. In some instances, resorbtion is almost complete, leaving ghost-textured relicts of sericite and quartz. Sericitization of the phenocrysts is common, and clinozoisite is often present, either as fine-grained inclusions or as large, core-crystals. Megacrystalline quartz phenocrysts were also observed in one sample.

The abundance of sericite and the presence of calcite and the epidote group of minerals within the phenocrysts indicates that the processes of alteration have been active. Heinrich (1965) states that epidote may form as a hydrothermal alteration-product, replacing plagioclase. As the products of alteration are, to a great extent, dependent on the pristine chemistry of the phenocryst, epidote and calcite were probably formed from a calcium-rich plagioclase, such as labradorite. Sericite is also a common alteration product of labradorite.

Light-brown, pink, and white-weathering rhyolites are common constituents of the Witfonteinrant Formation. Fresh surfaces are pink in colour, occasionally with diffuse, feldspar phenocrysts. The rhyolites outcrop as angular, massive boulders which are occasionally flow-banded (Plate 1e). The feldspar porphyries of the assemblage are easily weathered and poorly exposed. When weathered, they vary in colour from light-grey to dark-green with white speckles. Fresh surfaces are grey-to-brown, with light-coloured bands containing variable quantities of feldspar phenocrysts. The angular phenocrysts range up to 10 mm in diameter and are situated in a matrix which is generally composed of felsite, but may also be basaltic. Quartz porphyries are not as common as feldspar porphyries and are generally light-coloured and siliceous.

Variolitic lavas are common within the Formation and are best observed on the farm Welgewaagd 358 KQ. There is generally a strong colour contrast between the groundmass (dark-grey or green) and the varioles (light-brown, white, or pink). The varioles are generally almost perfectly spheroidal and range in diameter from over 10 cm to less than 1 cm. Variole density varies from flow to flow with lavas containing a large number of small varioles alternating with units with fewer, yet larger, structures. Small flows are characterized by a concentration of varioles in the upper part of the lava. The varioles are discrete, spherical bodies, but, if in juxtaposition, they generally have concavo-convex boundaties. Weak concentric zoning is evident in some varioles which have a dark core surrounded by a leucocratic outer zone. Variole-matrix contacts are sharply defined. In the groundmass, thin laminae, which are contorted both over and under the varioles, are often present, as are feldspar phenocrysts, which occur in both the groundmass and the varioles.

Thin basalt bands are accessory, but common, associates of the Witfonteinrant acid volcanics. They are dark-grey-to-black-weathering rocks which are easily weathered. Fresh surfaces are dark-grey and often have white calcite needles randomly scattered throughout the matrix. Lensoid, quartzo-feldspathic accumulations, up to 4 cm in length and orientated with their long axes horizontal, have been observed in some basalt bands. Others are amygdaloidal or massive. As the basic lavas are easily weathered, they are poorly exposed and give the impression that they are not continuous. Basalt bands are commonly closely related to sediments and either rest upon fine-grained clastics or are overlain by shales and cherts. If sediments are absent, pink rhyolite succeeds the basic lavas.

Three breccia varieties have been recognized within the Witfonteinrant Formation. The first is composed of chaotic, angular fragments up to 30 cm in diameter, bedded in an ash matrix. These breccias are thought to have their origins in the vent-facies of explosive volcanoes. The second type of agglomerate consists of poorly-sorted, rounded-to-angular clasts supported in an occasionally bedded and cross-stratified matrix composed of fragments and ash. These non-welded, matrix-rich breccias probably formed as lahars. The third breccia variety is observed in rhyolitic flows and consists of monolithologic, angular, unsorted fragments of rhyolite in a rhyolite matrix. These are considered to be massive, autoclastic breccias.

Fine-grained clastics, shales, and cherts are common in the Witfonteinrant Formation. Thinly-bedded, lithic arenites occur as two laterally-continuous bands, up to 3 m-thick, in the upper parts of the formation. Elsewhere, clastics outcrop as 1-2 m-thick lenses. Carbonaceous shale and siltstone units also outcrop as lenses throughout the succession in dark-grey, brown, or black, thinly-laminated beds. Lensoid-shaped chert bodies are commonly found in the lower parts of the Witfonteinrant Formation. They are usually dark-coloured, with thin, white laminae imparting a flat-bedded character to the lenses. On closer examination, some of the laminae are partially brecciated, with the white fragments being crudely imbricated. Intraformational breccias of this type are inferred to be the result of slumping of partically consolidated deposits. On the farm Nooigedacht 338 KQ, stromatolites were observed in two light-coloured chert lenses. The stromatolites have a columnar geometry, with columns ranging from 2 to 4 cm in diameter. The heights of each column range from 10 cm to over 60 cm. Laminae in the columns are continuous from one column to the next.

(ii) Geochemistry of the Acid Volcanics of the Witfonteinrant Formation

Six analyses of the acid volcanics of the Witfonteinrant Formation are presented. Table 2 lists the major-element geochemistry of three dark-coloured felsites, a feldspar porphyry, a pink rhyolite, and a variolitic lava. The average composition of the dark-coloured felsite (Table 2, Column 4) compares, in a general way, with the average composition of rhyolite (Table 2, Column 8). Individual analyses of the felsites show large variations, notably in SiO_2, total iron oxide, and K_2O contents (Table 2, Columns 1, 2, and 3). When compared with the average composition of rhyolite, the average composition of the dark-coloured felsites has a number of significant differences. Firstly, the Witfonteinrant Formation felsites are markedly deficient in Na_2O. Secondly, this relative deficiency in Na_2O is balanced by an enrichment in K_2O, a trend which is recognizable in all the analyses of Witfonteinrant Formation volcanics.

TABLE 2

Major-Element Chemistry of the Felsites and Rholites of the Witfonteinrant Formation, with Selected Comparative Analyses of Average Rhyolite and Lebombo Rhyolite

	1	2	3	4	5	6	7	8	9
	KB1 *	KB6 *	KB8 *		108Ad*	KB5 *	KB15*		
SiO_2	71,73	76,66	73,61	74,00	65,91	56,20	59,32	74,57	75,33
TiO_2	0,45	0,25	0,42	0,36	2,28	0,58	0,72	0,17	0,35
Al_2O_3	12,85	12,14	15,03	13,34	17,16	20,20	22,34	12,58	11,55
Total iron as Fe_2O_3	5,14	3,20	3,50	3,95	0,68	4,82	3,24	2,32	2,84
MnO	0,06	0,04	0,03	0,05	0,04	0,07	0,05	0,05	0,00
MgO	1,02	0,00	1,10	0,71	0,00	2,39	1,97	0,11	0,00
CaO	1,05	0,46	0,00	0,50	2,18	4,50	0,50	0,61	0,81
Na_2O	0,32	0,49	0,30	0,37	0,17	0,54	0,64	4,13	2,79
K_2O	7,01	6,89	5,59	6,50	10,43	7,61	8,92	4,73	6,15
P_2O_5	0,12	0,05	0,13	0,10	1,39	0,13	0,21	0,07	0,18
LOI	1,13	0,80	1,12	1,02	0,41	3,66	2,43	0,66	-
Total	100,88	100,98	100,83	100,90	100,65	100,70	100,34	100,00	100,00
Normative Corundum (Wt. per cent)	3,1	3,1	8,8	-	4,9	3,3	11,4	-	-

* Analyst - N. Tyler

1. Dark-coloured felsite, Kransberg 357 KQ.
2. Dark-coloured felsite, Kransberg 357 KQ.
3. Dark-coloured felsite, Kransberg 357 KQ.
4. Average composition of dark-coloured felsite, Witfonteinrant Formation (average of Columns 1, 2, and 3).
5. Pink rhyolite, Koedoevlei 128 KQ.
6. Feldspar porphyry (feldspar phenocrysts in a basaltic matrix), Kransberg 357 KQ.
7. Variolitic lava, Kransberg 357 KQ.
8. Average composition of 21 rhyolites (Nockolds, 1954, Table 1, Column IV).
9. Lebombo rhyolite, Mozambique (Cox et al., 1965, Table 40, Column 45, p. 198).

Column 5, Table 2, is an analysis of a pink rhyolite which has a relatively low silica-content of only 65,9 per cent. Comparable silica-contents are found in rhyo-dacites and dacites. However, when plotted on an An-Ab'-Or diagram (Figure 6, after Irvine and Baragar, 1971), the pink, flow-banded rhyolites plot in the potassic rhyolite field. Other peculiar characteristics of this lava are very high K_2O- and Al_2O_3-contents (10,43 per cent and 17,16 per cent, respectively) and low Na_2O-contents. Column 6, Table 2, provides an analysis of a feldspar porphyry composed of large phenocrysts embedded in a basaltic groundmass. When plotted on the ternary An-Ab'-Or diagram, the porphyry falls between the rhyo-dacite and K-andesite fields (Figure 6). High K_2O- and Al_2O_3-contents are present. Variolitic lava (Table 2, Column 7) exhibits a similar trend of high Al_2O_3- and K_2O-contents and a low Na_2O content.

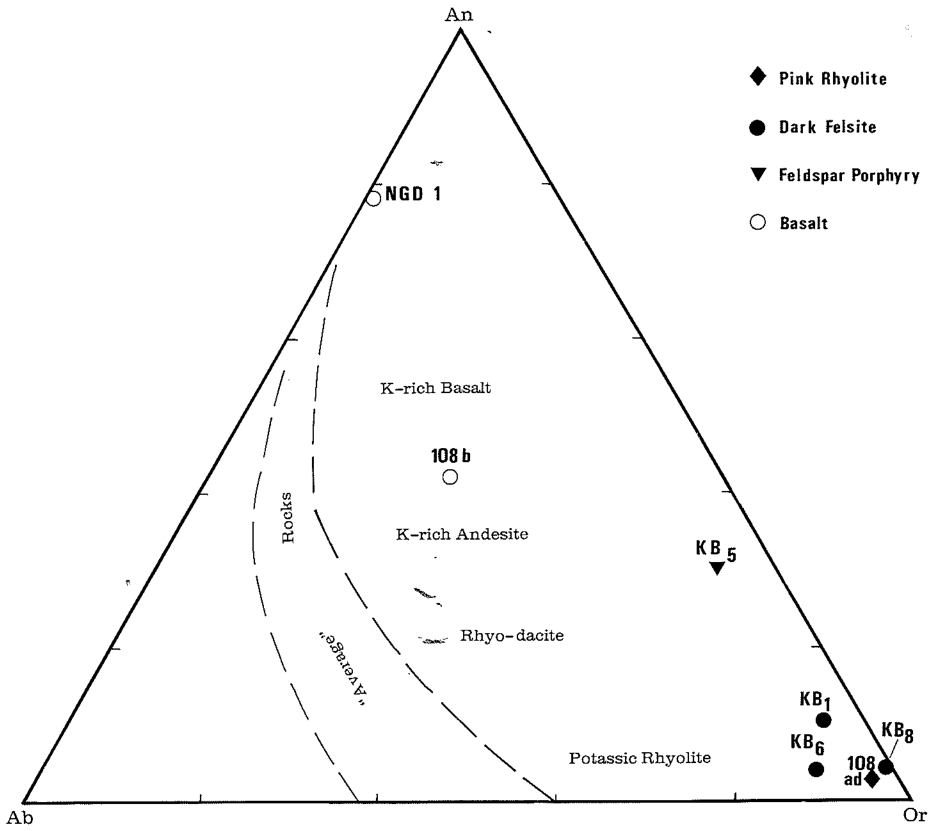


Figure 6 : *Plots of Buffalo Springs Group basalts (Waterval Formation) and acid volcanics (Witfonteinrant Formation) on an An-Ab'-Or diagram illustrating the strongly-potassic nature of the altered acid volcanics (after Irvine and Baragar, 1971; Ab' refers to normative Ab plus 5/3 normative nepheline).*

The normative corundum contents of these rocks average 5,8 weight per cent and vary between 3,1 and 11,4 weight per cent (Table 2), illustrating a trend towards extreme alumina-oversaturation. As normal volcanic rocks rarely have any normative corundum (Cornell, 1977), this trend towards alumina-oversaturation has been used as an indicator of alteration. In the case of the altered acid volcanics of the Seokangwana belt of the Ventersdorp Supergroup in the west-central Transvaal, a steady decrease in Na_2O- and Ca_2O-contents corresponds with increasing Al-oversaturation (Tyler, 1978, Figure 13). A similar plot of the Witfonteinrant Formation acid volcanics does not reveal any such trend, and element percentages vary without pattern.

The geochemical pattern that emerges from the acid volcanics of the Witfonteinrant Formation is one of enrichment in K_2O and deficiency in Na_2O, relative to the average composition of rhyolite. This is thought to be a result of regional alteration, but it might also reflect the original geochemistry of the lavas. Rhyolites of the Lebombo volcanic terrane (Table 2, Column 9) are similarly enriched in K_2O, but deficient in Na_2O, when compared with the average composition of rhyolite. This enrichment is not as marked as that of the acid volcanics of the Buffalo Springs Group, but indicates that the acid lavas of South Africa may be somewhat enriched in K_2O, when compared with the average composition of rhyolite.

(iii) The Depositional Setting of the Waterval and Witfonteinrant Formations

The absence of pillow-lavas and the presence of vent-agglomerates, laharic breccias, and pumice suggest that the extrusion of the Buffalo Springs volcanics was largely sub-aerial. Many of the lava-flows show typical terrestrial flow-features, including amygdaloidal tops and flow-top breccias. During periods of volcanic quiescence, standing-waters allowed suspension-sedimentation and formation of carbon-bearing shales.

Interbedded within the volcanic flows are sedimentary units, often with scoured bases and trough- and tabular-crossbeds. The sediments commonly grade upwards into wackes and clay-drapes which have, on occasion, desiccation-cracks. The clastics are immature and ill-sorted and generally occur as impersistent lenses, although two rather persistent bands are also present. These clastics are thought to have been deposited in a distal fluvial setting during periods of volcanic quiscence. The

The lensoid-shaped, dark-coloured cherts and the light-coloured stromatolitic cherts are inferred to have formed in bodies of silica-rich standing-water.

In summary, the volcanics and sediments of the Waterval and Witfonteinrant formations were deposited on a terrestrial volcanic terrane. During periods of quiescence, braided or meandering rivers migrated across the plain. In bodies of standing-water, shales and cherts were locally deposited.

E. The Kransberg Quartzite

Overlying the acid volcanics of the Witfonteinrant Formation is a persistent arenite unit which may be traced from Nooitgedacht 338 KQ to Kransberg 357 KQ, along a strike-length of 24 km. The arenite is conformable with the underlying Witfonteinrant Formation and is conformably overlain by, and grades upwards into, the Black Reef Quartzite (Figure 2). Although the upper contact is gradational, it is marked by a distinct change in the gradient of hillslope, from the cliff-faces of the Kransberg Quartzite to the gently-sloping hilltops underlain by the Black Reef Quartzite. Lithologically, the contact marks the boundary between the medium-to-coarse-grained arenites of the Kransberg Quartzite and the predominantly fine-grained greywackes and arenites of the Black Reef Quartzite. Exposures of the unit generally occur as cliff-faces which are, unfortunately, often sheared and brecciated, destroying many of the primary sedimentary structures.

The term Kransberg Quartzite was initially proposed by Marais (1967) who adopted the name from the farm Kransberg 357 KQ, in the Thabazimbi District. Before the work of Marais, previous investigators had not differentiated between the arenite body and the Black Reef Quartzite. Marais agreed with the current nomenclature of the time and correlated the underlying polymict sediments and basic and acid lavas (presently assigned to the Buffalo Springs Group) with the Dominion Reef Group. Subsequently, the Geological Survey's Thabazimbi Sheet (1974) also differentiated between the arenites, referred to as the Kransberg Quartzite, and the Black Reef Quartzite.

Measured sections traversing the Kransberg Quartzite reveal that the unit gradually thickens from zero in the north to over 60 m in the central and southern parts of the belt. The southern limit of the unit thins rapidly and pinches out over a palaeo-topographic high composed of acid volcanics of the Witfonteinrant Formation. The Kransberg Quartzite comprises fine-to-coarse-grained arenites, greywackes, and minor conglomerate.

Light-brown-to-white-weathering arenites predominate in the Kransberg Quartzite. The arenites are well-packed, but poorly-sorted and commonly have a bimodal grain-size, consisting of coarse-grained, well-rounded quartz clasts in a fine-grained angular-quartz matrix. Feldspars, rock fragments, calcite, sericite, and biotite are also common constituents. Primary sedimentary structures include swash-laminae, flat-bedding, stacked cosets of trough- and tabular-crossbeds, and stacked cosets of large-scale (up to 1,5 m in amplitude) asymptotic tabular-crossbeds (Plate 1f). The upper contact of the crossbedded unit is eroded by the subsequent crossbedded sediments to form regular, knife-sharp, upper and lower contacts (Plate 1f). Individual foresets vary up to 10 cm-thick and often have superimposed ripple-laminations on foreset-surfaces.

Poorly-sorted conglomerates generally occur as thin lenses in the arenites. Greywackes are common within the Kransberg Quartzite. They are fine-grained, immature rocks which are dominantly flat-bedded and occasionally are overlain by thin shale drapes. Mud-cracks are absent in the drapes.

Palaeocurrent work on the Kransberg Quartzite is difficult due to the brecciated nature of many of the outcrops. Readings were obtained from four stations within the arenites, which when plotted on a rose-diagram, reveal a bipolar, weakly-trimodal pattern (Figure 7a). Palaeocurrent directions recorded from one station on tabular-crossbeds alone reveal a strongly bimodal-bipolar pattern (Figure 7b) orientated at right-angles to the strike of the Kransberg Quartzite (Station Thaba 65a - Tygerkloof 354 KQ).

The depositional setting of the Kransberg Quartzite was influenced by a number of interrelated processes. Many of the arenite bands are texturally and mineralogically mature. Swash-laminae within these bands indicate deposition in a marine environment. Primary sedimentary structures in the less-mature arenites and greywackes, when considered together with the bimodal palaeocurrent pattern and the absence of any evidence of desiccation within the assemblage, suggest that deposition of the Kransberg Quartzite occurred in a tidal-influenced, shallow-marine setting. A detailed investigation into the depositional history of the Kransberg Quartzite has revealed that the arenites, conglomerates, and greywackes were deposited in a gently-sloped, high-energy, near-shore setting (Tyler, 1978). Strong longshore currents modified the orientation of the primary sedimentary structures, producing a palaeocurrent pattern that is directed essentially parallel to the palaeo-coastline (Figure 7a).

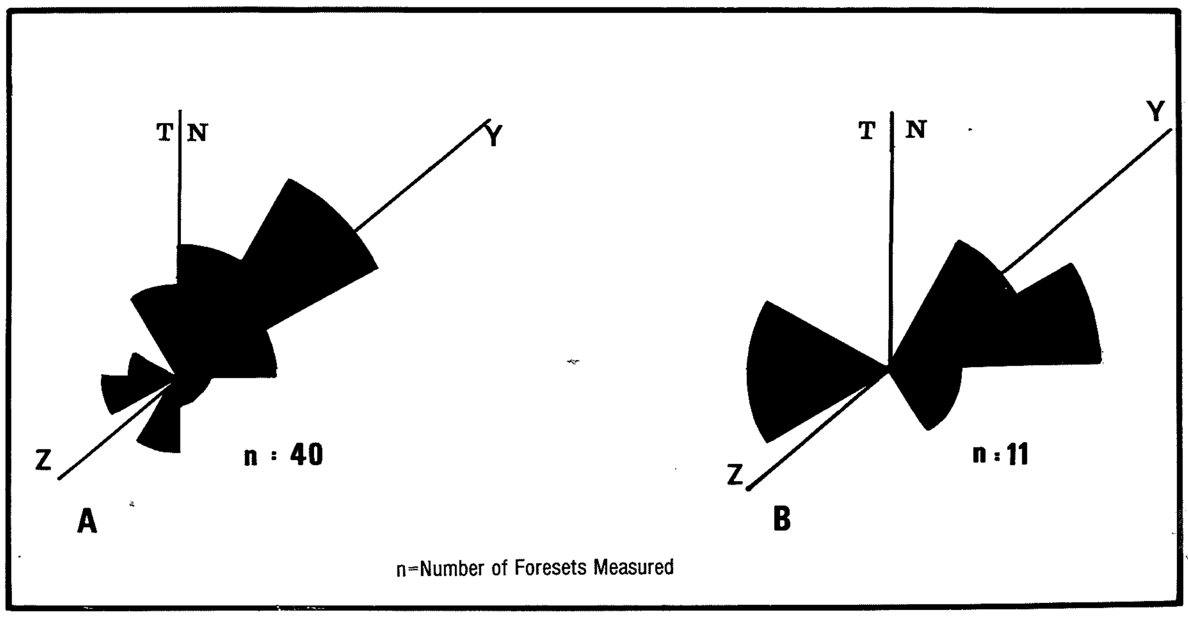


Figure 7 : *Rose-diagrams illustrating the bimodal, tripolar patterns of the Kransberg Quartzite (A), and (B) a single station within tabular-cross-bedded arenites. Y - Z is the average strike of the Kransberg Quartzite palaeo-coastline.*

III. THE CORRELATION OF THE BUFFALO SPRINGS GROUP

Any correlation of the pre-Black Reef stratigraphic assemblage developed to the north of the Ganskuil Platform must take into account the following :

(i) the basal sediments of the Hampton Formation unconformably overlie the Archaean granitoid rocks and greenstone remnants of the Makoppa Dome;

(ii) the Black Reef Quartzite conformably overlies, and has a gradational contact with, the upper sediments of the Kransberg Quartzite; only towards the margins of the assemblage does the Black Reef Quartzite overlap successively older units of the Buffalo Springs Group in a basin-edge unconformity; and

(iii) the basic volcanics of the Waterval Formation are basaltic and differ significantly from the "andesitic" lavas regarded by Winter (1965) as the unifying factor within the subdivisions of the Ventersdorp Supergroup in the type-areas established for these rocks.

Previously, the succession had been correlated with the Dominion Reef System (Truter, 1949; Schutte et al., 1960) and the Ventersdorp System (Kynaston, 1911; Thabazimbi Sheet of the Geological Survey of South Africa, 1974). Although point (i) above may be satisfied by both the previously-suggested correlations, the fact that the Buffalo Springs Group grades upwards into the conformably-overlying Black Reef Quartzite throws doubt upon either correlation. A gradational contact between two units indicates that the processes of formation continued without hiatus during the development of both units. Both the Kransberg Quartzite, which is inferred to have evolved in a near-shore setting, and the Black Reef Quartzite originated in a shallow-marine environment (Tyler, 1978). The gradational contact between the two units indicates the processes of sedimentation continued without break during their formation. Clearly, the correlation of the assemblage with the Dominion Reef Group, which is approximately 700 m.y. older than the Black Reef Quartzite, may be disregarded. Similar reasoning may be applied to the correlation of the succession with the Ventersdorp Supergroup which is approximately 300 m.y. older than the Buffalo Springs Group. This is further borne out by the significant differences in the geochemical character of the basalts of the Buffalo Springs Group and the basic-to-intermediate volcanics of the Ventersdorp Supergroup, regarded by Winter (1965) as the fingerprint of Ventersdorp volcanicity.

The work done on the northeastern parts of the Transvaal basin by Button (1973) revealed that the Black Reef Quartzite rested conformably upon an assemblage of predominantly-sedimentary rocks (the Wolkberg Group), which extends from north of Potgietersrus to Sabie, over a strike-length of 190 km. Briefly summarized, the 2 000 m-thick succession consists of a basal, coarse clastic unit overlain by a volcanic unit which is, in turn, succeeded by a variety of coarse clastics, fine-grained detritus, and shales. Button (1973) invoked a braided-fluvial depositional setting for the lower coarse clastics and deltaic, delta-front, mudflat, and prodelta environments for the finer-grained upper sediments. The volcanics were largely sub-aerially deposited. A gradational contact between the Black Reef Quartzite and the uppermost formation of the Wolkberg Group (the Sadowa Formation) was recognized by Button (1973). A number of similarities between the Buffalo Springs Group and the Wolkberg Group are tabulated in Table 3. The Buffalo Springs Group and the Wolkberg Group are comparable. Both have lower and upper sedimentary zones separated by volcanics. Maximum observed

TABLE 3

A Comparison Between Two Pre-Black Reef Quartzite Successions of the Transvaal Supergroup, the Wolkberg Group of the Northeastern Transvaal (after Button, 1973) and the Buffalo Springs Group of the West-Central Transvaal

	Wolkberg Group	Buffalo Springs Group
Lithology 1. Sediments	Coarse Clastics, Quartzites, Siltstones, and Shale	Similar (Coarse Clastics Dominant)
2. Volcanics	Basic	Basic and Acid
Maximum Thickness	2 000 m	2 000 m
Depositional Environments	Lower Sediments : Braided-Fluvial Upper Sediments : Shallow Marine	Braided-Fluvial Near-Shore Near-Shore
Maximum Thickness of Volcanic Units	Abel Erasmus Volcanics over 500 m	Witfonteinrant Formation over 800 m
Average Thickness of Sediments Overlying the Volcanic Units	565 m	40 m
Contact Relationship with the Black Reef Quartzite	Gradational, in part	Gradational, in part

thicknesses are comparable, and lithologies and depositional environments are similar. The Black Reef Quartzite is largely conformable above both lithologic successions and has a partly gradational contact with the upper formations of both the Buffalo Springs Group and the Wolkberg Group. The only difference between the two successions lies in the thickness of sediments which succeed the middle volcanic zones.

Consideration of the data presented above has led to the conclusion that the post-Makoppa Dome, pre-Black Reef rocks preserved in the Thabazimbi District, between Ganskuil and Sentrum, are the correlatives of the Wolkberg Group and, as such, constitute the proto-basinal phase of the Transvaal Supergroup in the west-central Transvaal.

IV. CONCLUSIONS

The succession of pre-Black Reef sediments and volcanics developed to the north of the Ganskuil Platform, between Ganskuil and Sentrum, in the vicinity of Thabazimbi, is correlated with the Wolkberg Group, as developed in the northeastern Transvaal. Sedimentation, with intermittent volcanic activity, continued almost without interruption from the base of the Hampton Formation to the final stages of the Pretoria Group. The Buffalo Springs Group is considered to represent the initial phase of Transvaal-age basinal development in the west-central Transvaal. Sediments of the Hampton Formation originated largely in a braided-fluvial system. In the northern parts of the basin, an early phase of sedimentation in a meandering river was followed by beach and shallow-marine activity in a high-energy, near-shore setting. The basalts of the Waterval Formation were succeeded by the extrusion of the acid volcanics of the Witfonteinrant Formation. Lavas were sub-aerially deposited, and, during interruptions in volcanicity, sedimentation occurred in a distal fluvial setting and in bodies of standing-water. The final chapter in the development of the Buffalo Springs Group was the near-shore and beach sedimentation of the Kransberg Quartzite. Shallow-marine sedimentation continued during the closing stages of Kransberg Quartzite accumulation and during the formation of the Black Reef Quartzite and the Chuniespoort Group.

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* *

APPENDIX I

Palaeocurrent Statistics - Buffalo Springs Group

Sedimentary structure measured is crossbedding, unless otherwise stated

Unit	Station	No. of Readings	Vector Magnitude (degrees true)	Consistency Ratio
Arkose-and-Shale Member, Hampton Formation	63A	10	142	0,85
	10C	8	154	0,89
	Flute Marks	11	167	0,76
Quartz Arenite Member, Hampton Formation	63E	11	296	0,84
	4D	13	192	0,58
	10D	12	011	0,88
	8I	22	170	0,61
	63D	2	073	0,90
Lower Arenite Member, Hampton Formation	18B	13	068	0,70
	30C	15	130	0,54
	36A	11	097	0,68
	50A	5	074	0,40
	46C	10	105	0,98
Greywacke Member, Hampton Formation	7I	12	127	0,85
	10I	13	230	0,96
	62A	7	176	0,87
	31E	14	145	0,75
Middle Arenite Member, Hampton Formation	17G	15	203	0,71
	18C	11	081	0,83
	22A	16	131	0,13
	29A (Antidunes)	15	251	0,50
	37B	6	219	0,37
	38A	12	239	0,80
Upper Arenite Member, Hampton Formation	44A	16	308	0,60
Kransberg Quartzite	65A	11	063	0,21
	41Z	11	356	0,26
	390Q	14	032	0,78
	33B	4	055	0,80

Total = 304

KEY TO PLATE I

A. The well-defined basal scour surface of the white band of the Quartz Arenite Member eroding into the underlying quartz wacke. (Koedoevlei 128 KQ, Thabazimbi District).

B. Low-angle discordancy separating 1-3 m-thick laminae sets (swash lamination) within the Quartz Arenite Member of the Hampton Formation. (Koedoevlei 128 KQ, Thabazimbi District).

C. Stacked cosets of ripple-cross-laminated wackes, Lower Arenite Member, Hampton Formation (Kameelpoort 332 KQ, Thabazimbi District).

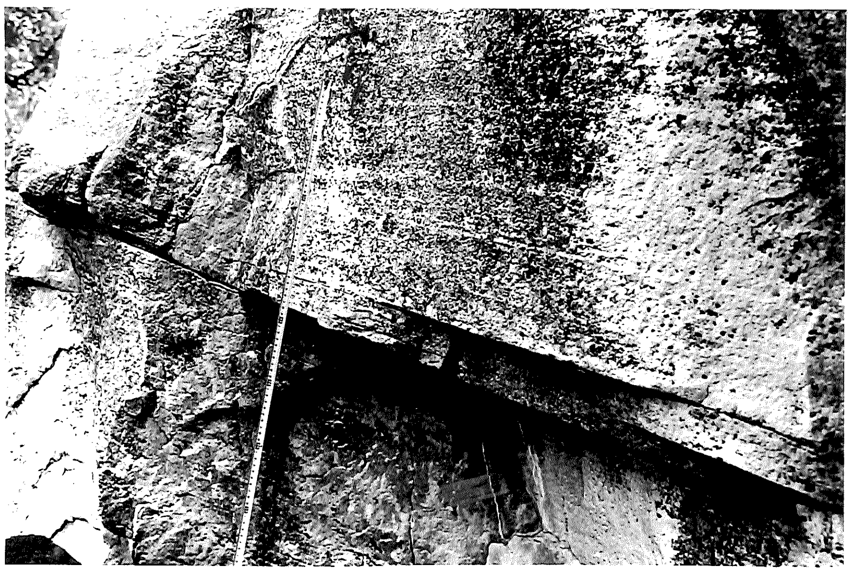
D. Preserved top-sets and brink-points suggesting weak depositional currents that were unable to erode to top-sets of the crossbeds. Greywacke Member, Hampton Formation (Koedoevlei 128 KQ, Thabazimbi District).

E. Flow-banded, light-coloured rhyolite of the Witfonteinrant Formation (Rotterdam 312 KQ, Thabazimbi District).

F. Steeply-dipping foresets in the tabular-crossbedded arenite. These foresets gradually become less steeply-dipping towards the base of the unit. The lowermost foresets are asymptotic and erode the underlying crossbeds. (Kransberg Quartzite, Kransberg 357 KQ, Thabazimbi District).

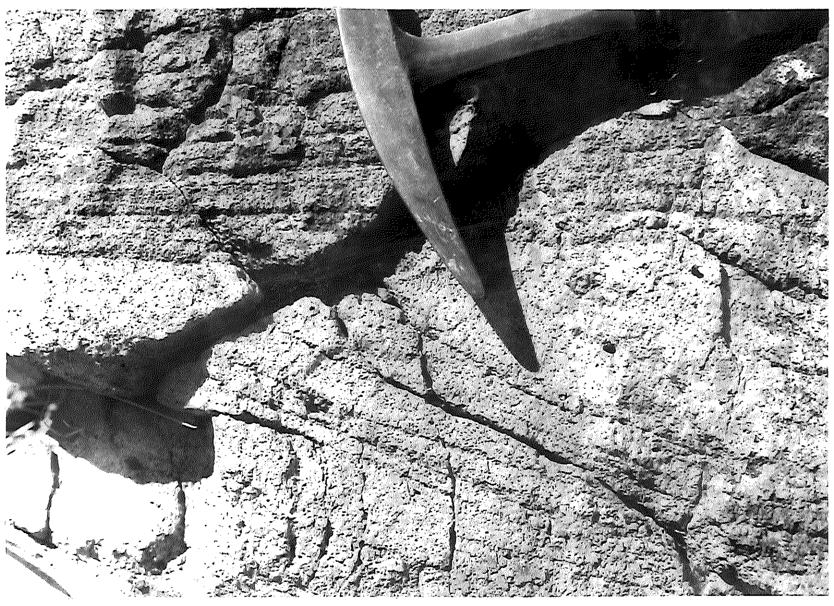
PLATE 1

A

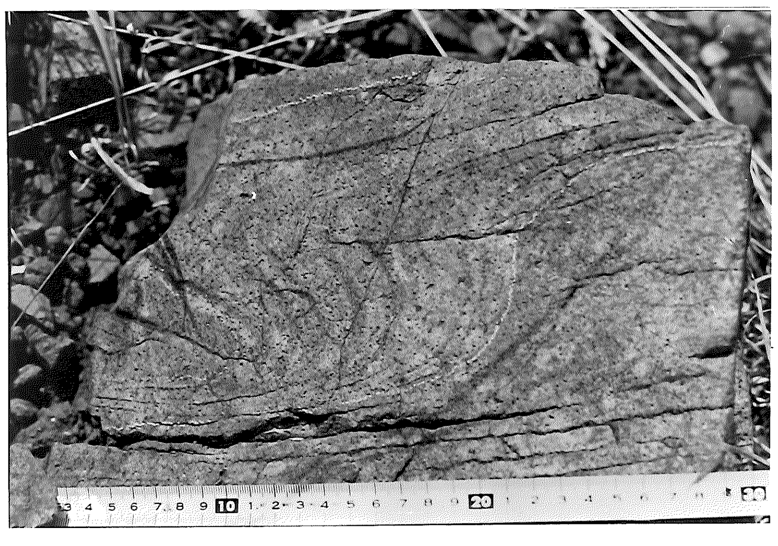


B

C



D



E

F