ECONOMIC GEOLOGY RESEARCH UNIT

University of the Witwatersrand
Johannesburg

EARLY-PROTEROZOIC MEANDERING-STREAM SEDIMENTATION IN THE BUFFALO SPRINGS GROUP OF THE TRANSVAAL SUPERGROUP, WEST-CENTRAL TRANSVAAL

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ABSTRACT

Few descriptions of meandering-stream sediments of Upper Palaeozoic age and older have been published in the geologic literature. The Arkose-and-Shale Member of the Hampton Formation, Buffalo Springs Group, Transvaal Supergroup, is composed of texturally- and compositionally-immature arenites and shales that comprise an 80 m-thick assemblage of rhythmically-stacked sets of fining-upward arenites, overlain by thick, mud-cracked shale. Shale bands, up to 5 m thick, comprise 26 per cent of the member. Primary sedimentary structures and lithologies have been used to interpret the facies of deposition of the assemblage. The Arkose-and-Shale Member is considered to have been deposited in a meandering-fluvial system, on the grounds of : evidence of desiccation; the relatively high shale content of the deposit; and the distinct cyclicity in the sequence, which is composed of upward-fining sets. Facies of deposition that are present within the Arkose-and-Shale Member are channel lags, lower and upper point-bar sediments, crevasse-splay clastics, and backswamp or flood-plain shales and silts. It is suggested that, during the Proterozoic, compaction of sediments or early diagenesis possibly contributed significantly to the stability of the bank and overbank components of the fluvial setting.

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INTRODUCTION

Descriptions of Upper Palaeozoic-to-modern, meandering-stream sedimentary deposits are common within the sedimentological literature. Less common are examples of meandering-fluvial deposits of Lower Palaeozoic and Proterozoic age. This paper describes an early–Proterozoic sedimentary assemblage thought to have originated in meandering-stream and backswamp depositional settings.

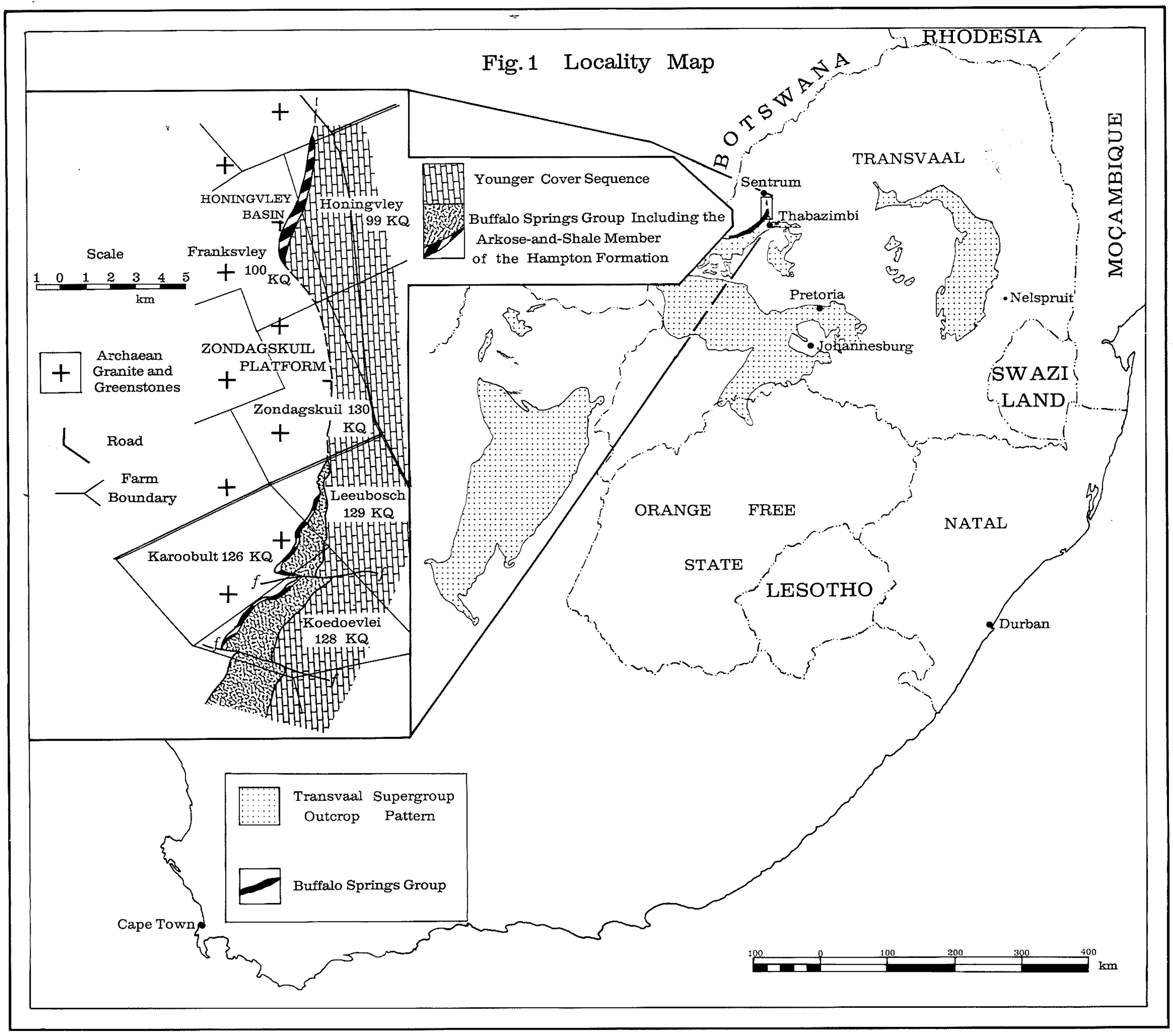


Figure 1 : Location and simplified geological setting of the Arkose-and-Shale Member, of the Hampton Formation, Buffalo Springs Group.

The sedimentary succession documented in this study outcrops at the base of the Transvaal Supergroup, to the west of Thabazimbi in the west-central Transvaal (Figure 1). Immature sediments that comprise the deposit outcrop in two narrow belts, one of which (the Honingvley Basin, Figure 1, inset) is extremely poorly-exposed. The second belt, situated to the south of a palaeotopographic high (the Zondagskuil Platform), is well-exposed along the cliff-faces of the Witfonteinrant on the farm Koedoevlei 128 KQ. For this reason detailed stratigraphic profiling was concentrated in this area.

GEOLOGICAL SETTING OF THE ASSEMBLAGE

The sedimentary succession documented in this study is located at the base of the 12 km-thick early-Proterozoic Transvaal Supergroup. The Transvaal Basin covers a large tract of the Southern African Shield (Figure 1) and probably had a depositional area of at least 500 000 km^2 (Button, 1973).

In the northwestern portion of the basin, the Transvaal Supergroup rests on Archaean basement and is intruded and overlain by the Bushveld Igneous Complex (Figure 2).

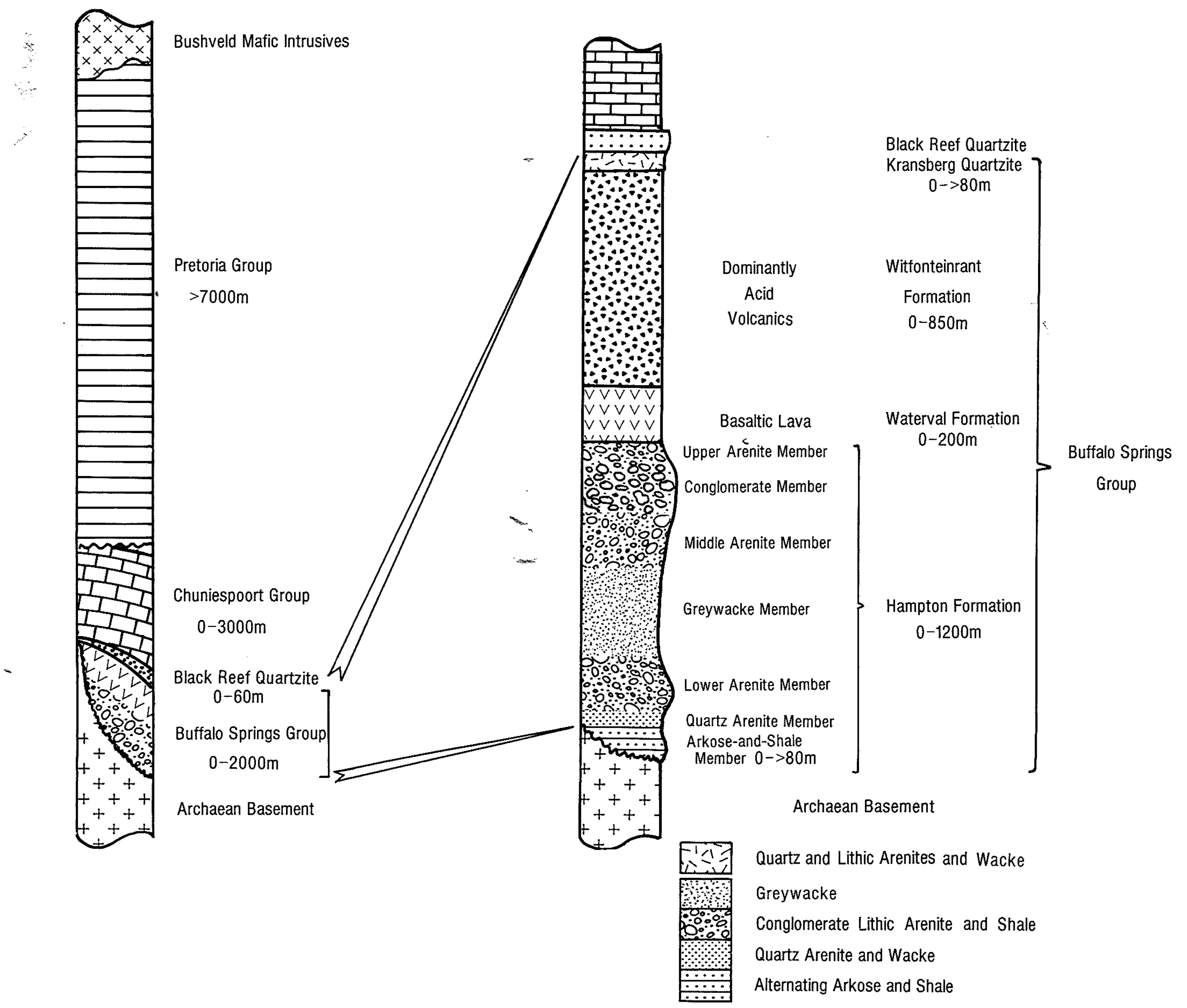


Figure 2 : Stratigraphy of the Transvaal Supergroup in the west-central Transvaal (left-hand column) and of the basal clastics and volcanics that comprise the Buffalo Springs Group (right-hand column).

The Buffalo Springs Group constitutes the proto-basinal phase of the development of the Transvaal Supergroup in the west-central Transvaal and has a maximum thickness of 2 000 m. A basal, predominantly fluvially-deposited sedimentary unit (the Hampton Formation, Figure 2, right-hand column) is overlain by the basaltic lavas of the Waterval Formation. Acid lavas, pyroclastics, sediments and basic lavas which constitute the Witfonteinrant Formation rest on the Waterval Formation and are, in turn, succeeded by arenites and wackes of the Kransberg Quartzite (Figure 2). The Kransberg Quartzite grades upwards into the base of the Black Reef Quartzite, which is a laterally-persistent sand-sheet that outcrops over most of the Transvaal Basin. The meandering-stream sediments described in this paper are located at the base of the sedimentary succession (in the Hampton Formation) immediately overlying the Archaean Basement.

The Transvaal Supergroup is considered to be between 2 200 and 2 300 m.y. old. Volcanics within the Pretoria Group (Figure 2) have been dated at 2 224 ± 21 m.y. (D. Crampton, quoted in Button, 1973), and the mafic rocks of the Bushveld Igneous Complex, which are intrusive into the Transvaal Supergroup, are estimated to be 2 095 m.y. old (Hamilton, 1975).

STRATIGRAPHY OF THE HAMPTON FORMATION

Immature volcaniclastic arenites and greywackes are the dominant constituents of the 1 200 m-thick Hampton Formation. At the base of the succession, overlying the Zondagskuil Platform (Figures 1 and 2), 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.

The Lower, Middle, and Upper Arenite Members are composed of lithic and arkosic arenites, matrix-supported conglomerates, wackes, and accessory amounts of mud-cracked shale. The Greywacke Member of the Hampton Formation (Figure 2) comprises fine-grained, matrix-rich wackes that gradually coarsen upwards into the Middle Arenite Member. This upward-coarsening cycle continues through the Middle Arenite Member and is terminated by the two lobes of the Conglomerate Member - a unit composed of cobble and pebble conglomerates that grade both laterally and vertically into cross-laminated sands. The arenite, conglomerate, and greywacke members of the Hampton Formation were deposited in a braided-fluvial setting (Tyler, 1978) and will not be further discussed in this paper.

STRATIGRAPHIC RELATIONS AND LITHOLOGY OF THE ARKOSE-AND-SHALE MEMBER OF THE HAMPTON FORMATION

The Arkose-and-Shale Member of the Hampton Formation (Figure 2) presently exposed in the Honingvley and Buffalo Springs Basins (Figure 1, inset) has a total strike-length of 13 km. The two troughs of preservation are separated by a palaeotopographic high, the Zondagskuil Platform (Figure 1, inset), which is composed of Archaean granites and greenstone remnants. To the north of the Zondagskuil Platform, the Honingvley Basin is completely filled with arkosic arenite and shale. Hematitic replacement of individual shale bands has often been observed in this basin. Exposure of the arenites in the Honingvley Basin is extremely poor, and thus this sequence was only studied in a general way. South of the granitic palaeotopographic high, the arkosic arenites and shales are well exposed. Measured sectioning revealed a thickness of over 80 m, composed of rhythmically-stacked sets of upward-fining cycles (Figure 3) which grade from coarse-granule conglomerate to thinly-laminated shale. Although the overall pattern is one of fining-upwards, each individual cycle is composed of very coarse arkosic sands 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. The finer-grained elements of the succession (shale and siltstone) comprise 26 per cent of the assemblage (Figure 3).

Two major lithologic facies are present within the arkosic arenite-shale assemblage. The characteristics of the deposits and their suggested origins are described below.

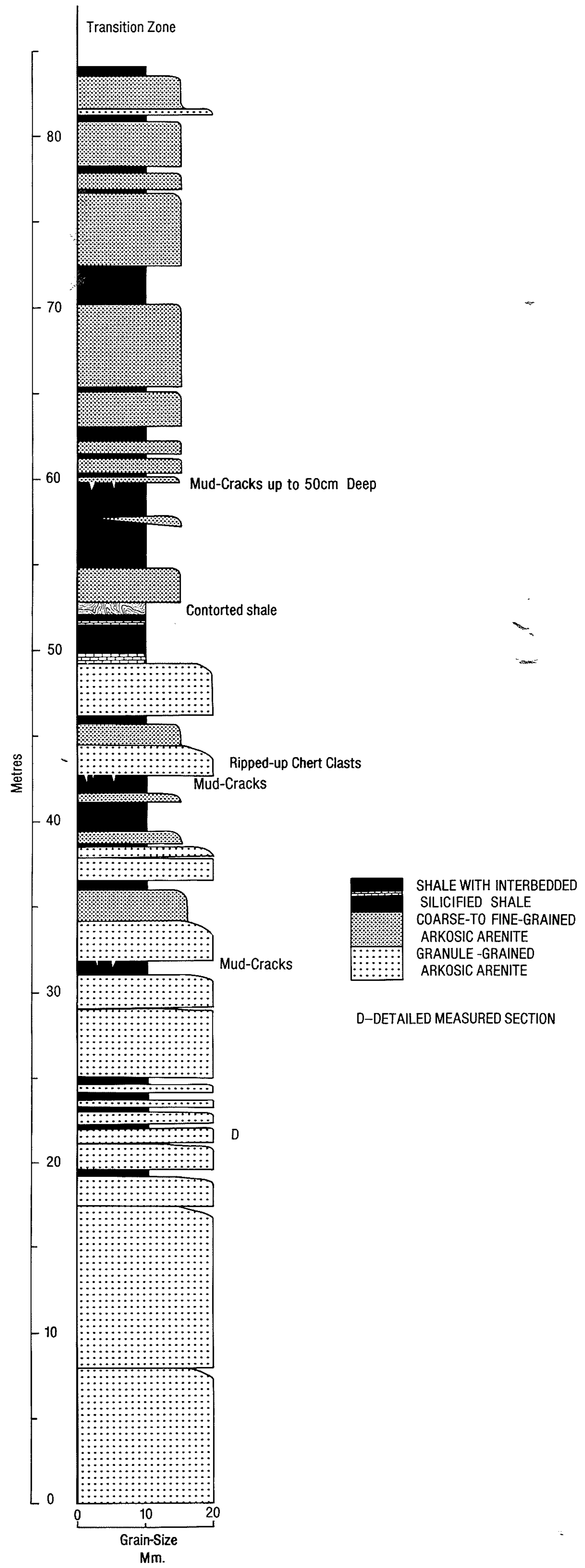
Arkosic Arenites and Wackes

Coarse-grained, arkosic arenites predominate in the lower parts of the succession. The arenites comprise ill-sorted, angular-to-subrounded, feldspar clasts varying up to 20 mm in diameter, with finer-grained interstitial quartz. Fresh outcrop surfaces are pink-coloured, a tint imparted by the high proportion of feldspar. Both the feldspar and quartz clasts are set in a greenish-brown micaceous matrix. Pyrite crystals up to a centimetre in diameter, altering to hematite, are common.

Thin-section examination (Thaba 63A) reveals that the feldspar is sericitized microcline, with occasional microcline, microperthite, and plagioclase clasts. The matrix consists of coarse biotite, fine-grained sericite (which is commonly hematite-stained), dusty opaque minerals, quartz, and feldspar. A point-count analysis (500 observations) revealed that the rock is composed of 49 per cent quartz, 36 per cent feldspar, and 15 per cent matrix, and can be classified as an arkosic arenite according to Dott (1964). Point-count analyses on samples taken higher in the column confirm a gradual decrease in feldspar content, with a corresponding increase in the proportion of matrix. Sample Thaba 12b, taken near the top of the Arkose-and-Shale Member, has finer-grained, subrounded feldspars comprising only 26 per cent of the rock. The matrix constitutes 23 per cent of the sample. The substantial increase in the matrix and decrease in the feldspar content of the sample is such that the rock can be classified as an arkosic wacke (matrix-rich arkose).

Individual bands of arkosic arenite and arkosic wacke are generally terminated by a thin zone (up to 10 cm thick) of rapidly-upward-fining grain-size. These zones are overlain by siltstones and shales of varying thickness. The arkosic arenites have grain-sizes dominantly in the coarse sand range, although granule-sized clasts are also present.

Primary sedimentary structures within the arkosic arenites are illustrated in Figures 4 and 5. The base of each arenite band is generally a scour-surface cut into the underlying shaly unit. Scour-and-fill structures vary in scale from small to large (Figure 5), with depths of up to 2 m. Trough-crossbed sets are generally found in the lower parts of the arenite bands and are succeeded by plane beds with occasional troughs (Figure 5). Intraclasts of silicified shale are commonly associated



<u>Figure 3</u> : *Detailed measured section through the Arkose-and-Shale Member of the Hampton Formation, illustrating the graded cycles, the regular cyclicity, and the high shale content (26 per cent) of the assemblage (Koedoevlei 128 KQ, Thabazimbi).*

with the scour structures (Figure 5). 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.

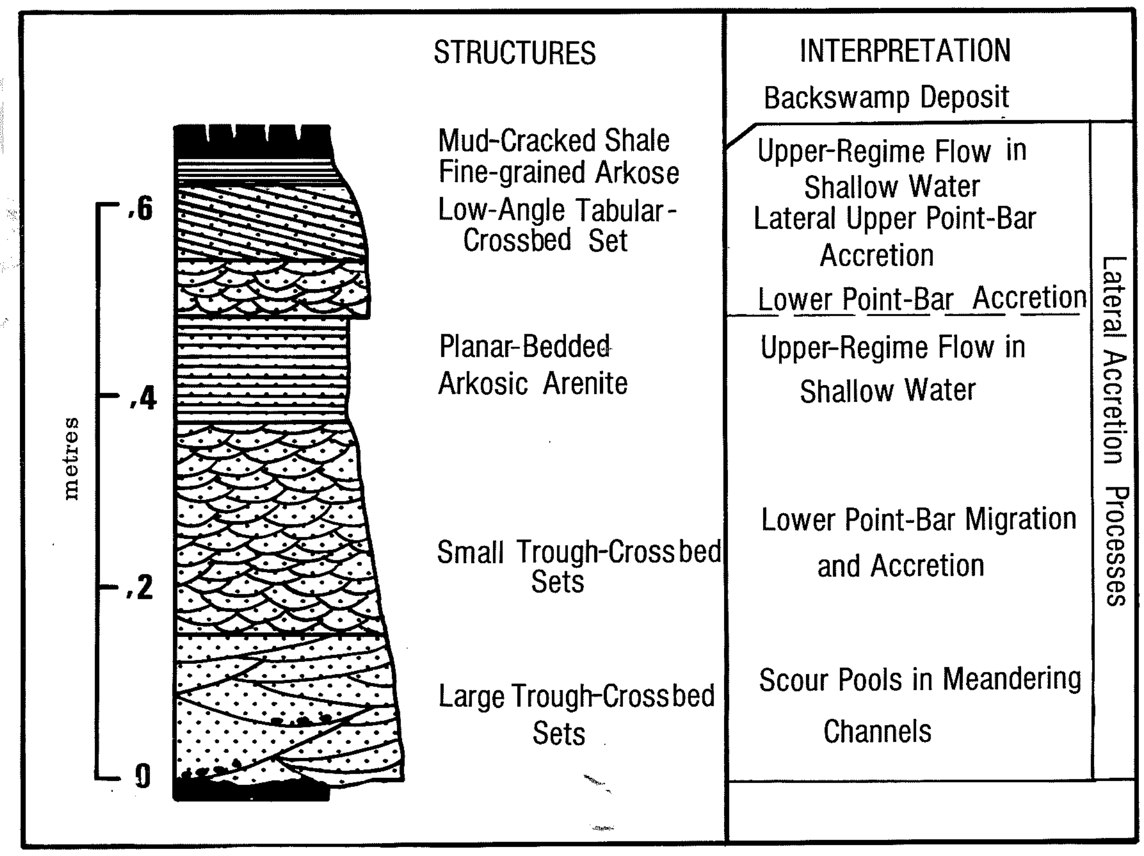


Figure 4 : *Detailed measured profile through an arkosic arenite band, illustrating the interplay of various fluvial processes in a meandering-stream setting (Arkose-and-Shale Member, Koedoevlei 128 KQ, Thabazimbi District).*

Due to the difficulties of palaeocurrent measurement on cliff-faces and the relatively poor development of sedimentary structures within the coarse clastics, only a small amount of palaeocurrent data has been collected (Table 1). The arkosic arenites and wackes were deposited by directionally-persistent distributive currents moving from the northwest. The palaeocurrent data agreed with the directional measurements made on flute-casts.

Station	No. of Measurements	Vector Mean (degrees true)	Consistency Ratio
63A	10	142	0,85
10C	8	154	0,89
Flute Casts	11	167	0,76

Table 1 : *Palaeocurrent statistics for the Arkose and Shale Member, Hampton Formation*

The coarse-grained arkosic arenites and wackes are thought to represent bed-load sediments deposited in a meandering-channel system. This will be discussed in the following section.

Shale and Siltstone

Thinly-laminated shale dominates the finer-grained elements of the Arkose-and-Shale Member (Plate 1a). When weathered, the shale varies between dark grey and dusky green in colour, often with thin, red bands. Graded beds, commencing with red-weathering sands and passing up into silts, are common. Scattered feldspar grains and coarse arkosic wacke lenses (Plate 1b), which have sharp basal contacts and gradational upper surfaces, characterize a number of the shale bands. Shale clasts are often present in the arkosic arenite lenses.

Intrastratal slip of the relatively competent arkosic arenites over the relatively incompetent shale unit has caused contortion of the upper parts of one of the shale bands (Plate 1c and Figure 3). With depth, the amplitude of contortion decreases and passes into undisturbed shale. The subparallel, minor-fold axial planes all dip inwards, towards the centre of the basin, indicating that, on subsidence, the overlying arenite band moved outwards over the shale, dragging the uppermost laminae with it.

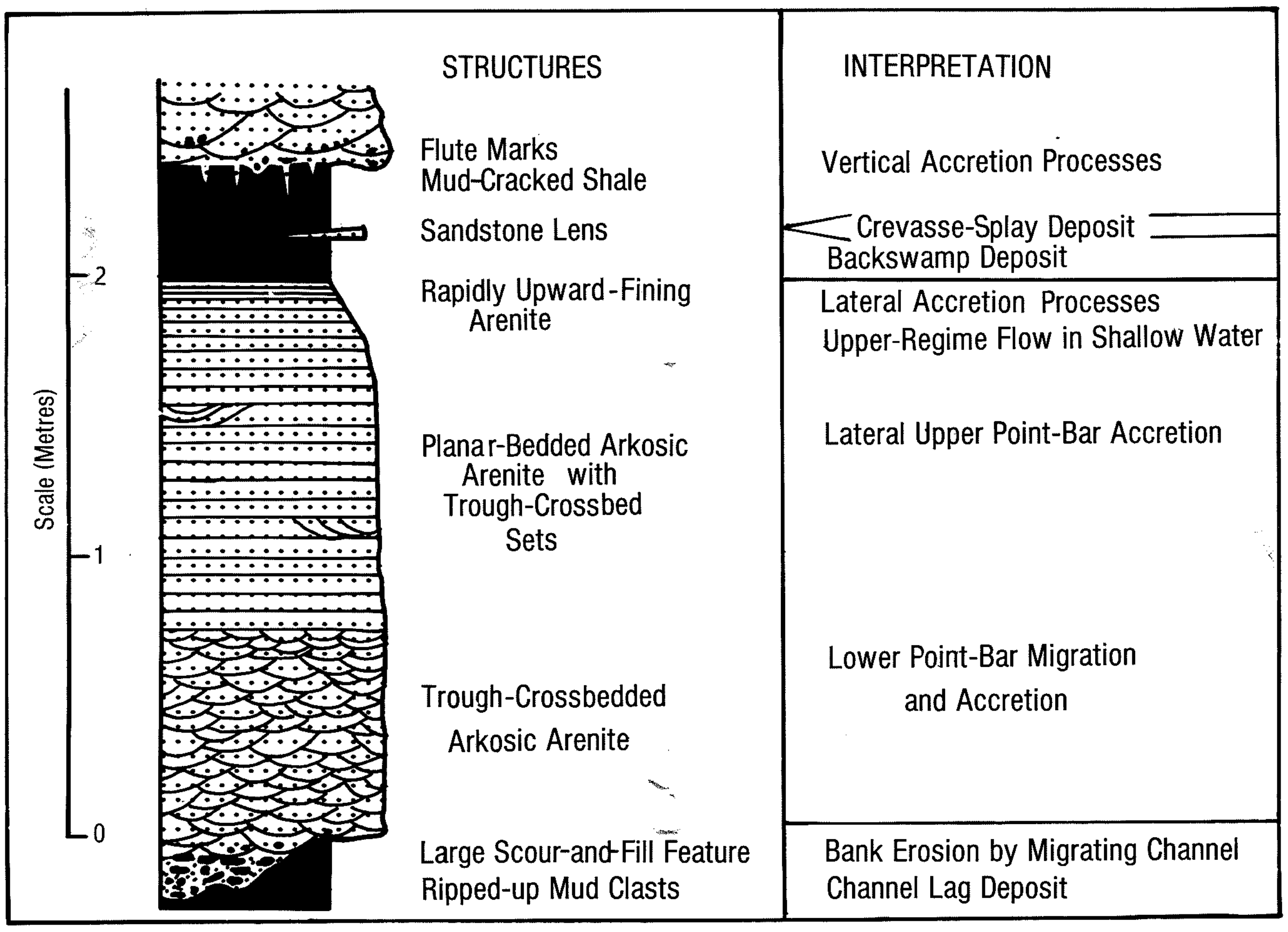


Figure 5 : *Schematic profile through an arkosic arenite band, illustrating primary sedimentary structures and their interpretation (Arkose-and-Shale Member, Koedoevlei 128 KQ, Thabazimbi District).*

Mud-cracks (Figures 4 and 5) are common in the thinly-laminated shales. In vertical section, the mud-cracks occur as detritus-filled, V-shaped extensions of the overlying arenites into the underlying shale. They vary from a few millimetres to more than 50 cm in depth.

Silicified shale is present in thin layers in the arkosic arenite and shale bands. The silicified shale is usually brown-to-dark-grey in colour and is volumetrically insignificant when compared with the total volume of the member. Graded beds have been noted in some bands.

THE DEPOSITIONAL SETTING OF THE ARKOSE-AND-SHALE MEMBER

A number of features assist in interpreting the depositional setting of the Arkose-and-Shale Member : the arkosic arenites and wackes are texturally- and mineralogically-immature, indicating a depositional environment of limited reworking and rapid sedimentation; the assemblage has a distinct and regular cyclicity, with continuous, near-parallel shale bands alternating with coarse-grained detrital units; each cycle comprises an upward-fining, graded sequence from coarse-grained sands, through fine-grained sands, to a termination of shale and interbedded silts; the terminating shaly component of the upward-fining cycles are often mud-cracked, indicating periodic exposure and desiccation; and, the bases of the coarse, detrital units are major scour-surfaces which erode the underlying shales.

These criteria, when considered together with the unimodal palaeocurrent pattern of the Arkose-and-Shale Member, 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. The high percentage of shale (which constitutes 26 per cent of the column) indicates that deposition occurred in a meandering-fluvial system, rather than in a braided-fluvial system, for, according to Allen (1965), shale and siltstone have low preservation-potentials in braided streams and are poorly represented. Other features confirming this suggestion are the regular cyclicity of the assemblage, and the abundance of classic, fining-upward graded cycles. Braided-stream systems, because of their highly variable discharge characteristics and continuously-migrating channels, generally produce chaotic vertical sequences. The Arkose-and-Shale Member is, however, composed of rhythmically-interlayered arkoses and shales.

Sedimentary structures in the arenite bands have been used to interpret the facies of deposition within the meandering-stream setting. Scoured surfaces at the base of each arenite band were probably eroded in scour-pools at the bottom of a river-channel. The large scour-and-fill features which incise into the underlying shale (Figure 5), with reliefs of up to 2 m, are interpreted as erosion of the concave bank of a migrating channel. Allen (1964) has described a similar structure, with a relief of 4,8 m, in the fluvial sediments of the Lower Old Red Sandstone, Anglo-Welsh Basin.

Scoured surfaces are commonly followed by intraformational conglomerates comprising mud-clasts, interpreted as channel-lag deposits. Because the basal, scoured surface probably originated as the river migrated across a flood-plain built from earlier alluvium, it is inferred that the siltstone-clasts overlying the scoured surface were derived from bank erosion.

The trough-crossbedded, arkosic arenites, generally observed overlying the channel-lag deposits (Figure 5) and resting upon scoured surfaces (Figure 4), are considered to be the result of down-stream dune migration during lower-point-bar accretion processes. According to Reineck and Singh (1973), point-bar deposits in modern meandering streams of low sinuosity and rather high gradient may be classified into lower- and upper-point-bar sequences. The lower-bar consists of trough-cross-bedded sands and is often overlain by tabular-crossbed sets derived from laterally-accreting upper-bar deposits (Allen, 1964; Reineck and Singh, 1973). Sedimentary structures illustrated in Figure 4 are interpreted as lower and upper point-bar deposits.

Plane-beds with local cross-stratification (Figures 4 and 5) in meandering-stream systems are regarded by Allen (1964) as sand accumulated on submerged, flat-topped banks from upper-regime flow. Decreasing flow-velocity accounts for the rapid upward-fining in grain-size, followed by thin, mud-cracked, shale drapes, indicating vertical accretion from standing water and subsequent desiccation on exposure of the point bar.

The thick shale bands (Figure 5) are inferred to have formed by vertical accretion from overbank floods. Thin sandstone lenses within the backswamp deposits probably represent crevasse-splays. Allen (1964 and 1965) has stated that crevasse-splay deposits occur beyond the main stream channel when excess water leaves the channel through isolated low sections or breaks in the natural levee. Rip-up shale clasts within the arkose lenses suggest that erosion of the overbank deposits preceded deposition of the splay deposit. Periodic exposure of the backswamp deposits caused desiccation and the formation of mud-cracks.

The cyclicity of the Arkose-and-Shale Member, Hampton Formation, has three possible explanations (Allen, 1964) : firstly, the rivers may have migrated back-and-forth across a portion of the flood-plain, under conditions of steady subsidence and sediment-supply; secondly, influenced by sea-level changes, the rivers alternately eroded and aggraded the flood-plain under steady subsidence and sediment-supply conditions; or the third possibility is that bursts of tectonic activity in the source-area led to an increased sediment-supply, and alternating erosion and aggradation in the flood-plain. The three possible explanations will remain speculative, because of the limited exposure of the Arkose-and-Shale Member. However, the fact that the overlying Quartz Arenite Member (deposited in a nearshore marine setting) transgresses the terrestrial sediments of the Arkose-and-Shale Member confirms that changes in sea-level played an important role during the genesis of the lower members of the Hampton Formation.

The characteristics of the Arkose-and-Shale Member compare favourably with descriptions of Recent-to-Upper Palaeozoic meandering-stream deposits. However, many of the accounts of modern meandering-fluvial successions have emphasized the importance of vegetation as a bank-stabilizing agent. During the Proterozoic, although land-plants had not yet evolved, the overbank deposits appear to have been relatively stable. This is indicated by the high shale content of the assemblage and the angular relationship between the eroded, shaly bank and the coarse-grained, channel deposit. This would suggest that during the Proterozoic, other factors, for example the compaction of sediments or early diagenesis, possibly contributed significantly to the stability of bank and overbank components of the fluvial setting.

In summary, the Arkose-and-Shale Member of the Hampton Formation has many characteristics in common with recent and fossil meandering-stream environments. Coarse clastics in the member are considered to have been deposited within the confines of a meandering channel during normal-water stages, as channel-lags, and during lower and upper point-bar accretion. The finer fraction of the sequence is inferred to have originated within the backswamp or flood-plain setting during flood or high-water stages. Processes operative in this facies were vertical accretion from overbank floods and desiccation during periods of exposure. Breaks in the natural levees of the deposit allowed crevasse-splaying to occur, which is represented in the succession by thin sandstone lenses within the shale bands. The environment of deposition of the Arkose-and-Shale Member and the relation between the genetic types of facies within the meandering-stream setting is schematically illustrated in Figure 6.

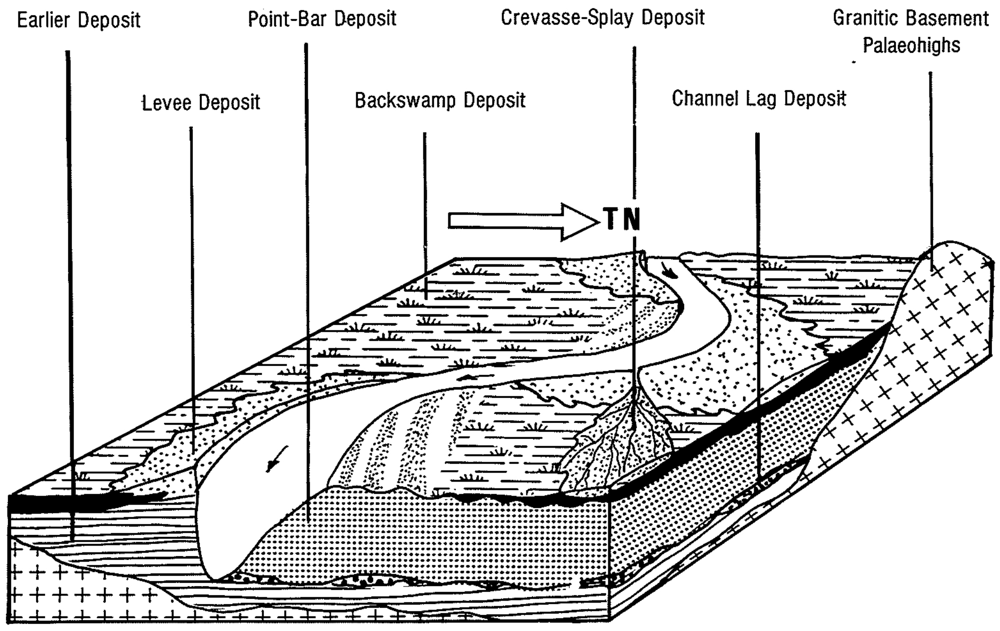


Figure 6 : *Block diagram illustrating the inferred depositional environment of the Arkose-and-Shale Member, Hampton Formation, and the relation between the genetic types of flood-plain deposits in an idealized flood-plain with a meandering river (after Allen, 1964).*

Acknowledgements

This study represents portion of a regional stratigraphic investigation of the early-Proterozoic geology of the west-central Transvaal. The author gratefully acknowledges funding provided by the Johannesburg Consolidated Investment Company Ltd., for the project.

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Plate 1(a) : *Thinly-laminated shale (Koedoevlei 128 KQ, Thabazimbi District).*

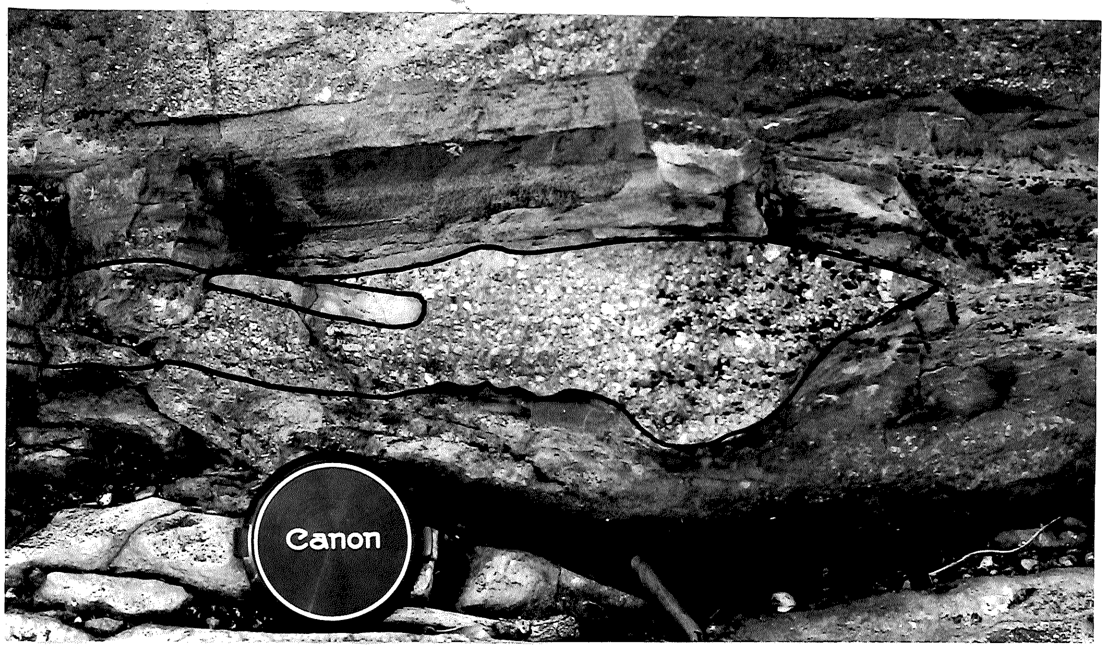

Plate 1(b) : *Coarse arkosic arenite lens (outlined) in thinly-laminated shale. Note the rip-up mud clast (Koedoevlei 128 KQ, Thabazimbi District).*

Plate 1(c) : *Contorted shale in the Arkose-and-Shale Member. Parallel fold axial-planes all dip towards the centre of the basin. Intrastratal slip of the overlying competent arkosic arenite over the relatively incompetent shale unit is thought to be the mechanism of deformation (Koedoevlei 128 KQ, Thabazimbi District).*