ECONOMIC GEOLOGY RESEARCH UNIT

University of the Witwatersrand
Johannesburg

FLUVIAL AND TIDAL SEDIMENTATION IN THE MOZAAN BASIN OF THE PONGOLA SUPERGROUP

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by

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ABSTRACT

The 3 000 m.y.-old Mozaan Group of the southeastern Transvaal, northern Natal, and Swaziland, comprises three interacting sedimentary environments : (1) braided alluvial plain; (2) offshore shelf; and (3) tidalite. The predominance of planar cross-bedded sandstones in the fluvial sequence indicates that sedimentation was dominated by southerly-accreting transverse bars in a distal braided river system. However, the development of lenticular conglomerates suggests the occasional formation of longitudinal gravel bars, probably during periods of high discharge. Argillaceous sediments, some of which are ferruginous, represent an interplay between clastic sedimentation and chemical precipitation on a prograding shelf. The abnormal thickness of these shelf deposits is attributed to facies-stacking. The absence of barrier-beach deposits suggests that the marginal-marine environment was controlled by macro-tidal conditions. Two varieties of tidal sequences are recognized. The first, which forms the classic upward-fining succession contains ubiquitous ebb-dominated paleocurrents and is interpreted as having been influenced by tidal asymmetry. The other, which lacks the mixed-flat unit, was apparently generated by tidal currents flowing parallel to the coastline. The nature of the Mozaan sediments suggests incipient cratonization in eastern South Africa 3 000 m.y. ago.

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CONTENTS

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INTRODUCTION

The early Precambrian Mozaan Group is exposed in a series of open structural basins in eastern South Africa (Fig. 1). The Mozaan consists essentially of clastic sediments which have suffered negligible regional metamorphism, and these, together with the underlying, predominantly volcanic Insuzi Group, comprise the Pongola Supergroup. An age of about 3 000 m.y. is suggested for the Pongola Sequence by its sedimentary contact with an underlying granite dated at 3 060 m.y. (Hunter, 1974) and the intrusion of the 2 870 m.y.-old Usushwana igneous suite (Davies et al., 1969).

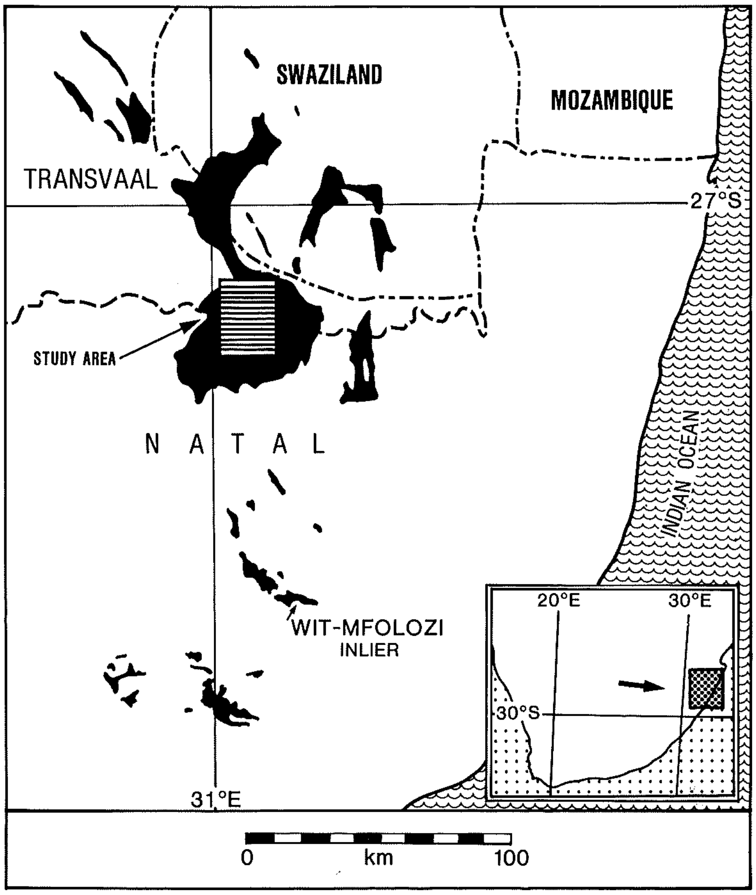


Figure 1 : Distribution of Pongola Supergroup exposures.

The present study was undertaken in an attempt to establish a paleoenvironmental model for the western portion of the Mozaan depository, in the hope that it would give some insight into the prevailing tectonics at the time of deposition. The only previous sedimentological work on the Mozaan was carried out at Wit-Mfolozi (Fig. 1), where von Brunn and

Hobday (1976) interpreted that portion of the basin as having been deposited in a macrotidal environment, with some evidence of fluvial activity.

SEDIMENTARY FACIES

The Mozaan Group comprises an alternation of arenites and argillites within which nine sedimentary lithofacies have been distinguished on the basis of composition, texture, and sedimentary structures. These constitute three interacting depositional environments, namely, braided alluvial plain, offshore shelf, and tidalite.

(a) Braided Alluvial Plain

Planar cross-bedded and plane-bedded quartz arenites characterize the bulk of this facies assemblage (Fig. 2), although less mature sandstones do occur. The preponderance of planar cross-stratification, which displays a unimodal southerly paleocurrent pattern (Fig. 3), the paucity of fine-grained sediments, and the absence of vertical textural trends resemble the distal braided reaches of the modern Platte River, Nebraska (Smith, 1970; Miall, 1977). Both angular and tangential planar foresets are represented, the latter occasionally being accompanied by regressive ripples. These structures suggest fluctuations in sediment load (Jopling, 1965), possibly related to low- and high-water stages, respectively. The low variance of paleocurrent data from this facies, relative to that produced in similar modern environments (Smith, 1972), has been attributed to the low preservation potential of slip-faces subparallel to the flow direction (Banks and Collinson, 1974). Plane beds, which are commonly superimposed on planar cross-bed sets are interpreted as bar-top sediments which accumulated in response to vertical accretion. The absence of primary current lineation is ascribed to the degree of recrystallization that these sandstones have undergone. Thin cosets of graded horizontal laminae (Fig. 4) indicate the possibility that some of the plane beds were deposited in the lower-flow regime by the accretion of low-amplitude sand-waves over the bar-top (Smith, 1971).

One of the fundamental processes whereby braiding develops in the distal reaches is the dissection of transverse bars (Smith, 1970). Possible evidence of this mechanism is provided by elongate channels containing single sets of trough cross-stratification (Fig. 5).

Occasional lenticular matrix- and clast-supported conglomerates are interbedded within the sandstones. These conglomerates have a maximum thickness of 2m, and individual pebbles, which tend to be angular-to-subrounded, have a maximum diameter of 15cm. The matrix-supported conglomerates may display a crude horizontal stratification, whereas the clast-supported variety is apparently massive. These conglomerates are interpreted as longitudinal bars which accumulated during extreme discharge. Similar gravel bars have been documented in the distal Platte River (Miall, 1977). Rare lensoid shale interbeds, up to 30cm thick, are interpreted as abandoned channel deposits. The infrequency of these argillaceous sediments is characteristic of braided streams (Cant and Walker, 1976; Long, 1977) and may be attributed to the flushing of fines into the basin, thereby inhibiting the development of an extensive floodplain.

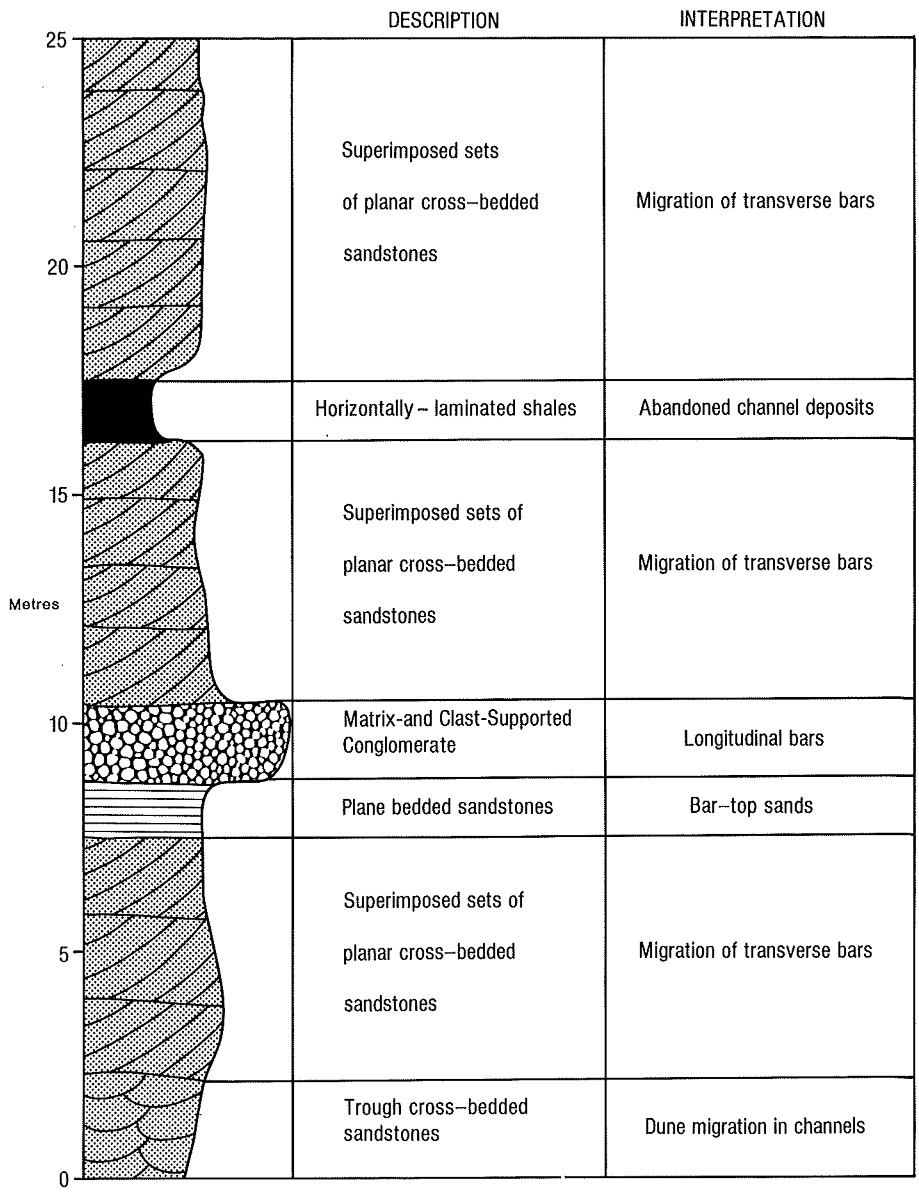


Figure 2 : *Stratigraphic section and paleoenvironmental interpretation for the braided alluvial plain.*

The anomalous maturity of the fluvial sandstones is attributed to the presence of pre-Pongola sediments in the source-area. This is borne out by the presence of polycrystalline quartz and chert grains and by quartzite and chert pebbles.

(b) Progradational Shelf

This is expressed as an upward-coarsening sequence with lenticular bodies of iron formation as its lowermost unit (Fig. 6). These comprise a rhythmic interlamination of magnetite and grey chert or jasper, which display localized contortions (Fig. 7). The close alignment of the fold axes within the banded iron formation with the regional structure suggests that the folding is of tectonic origin. The occurrence of magnetite in

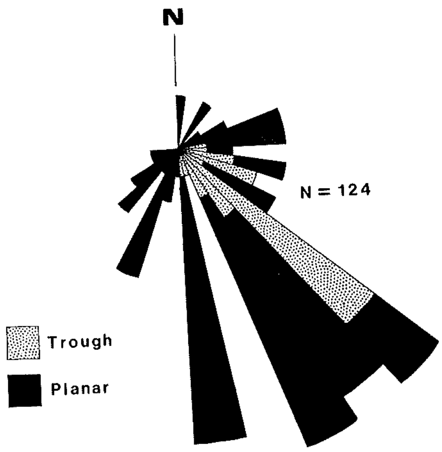


Figure 3 : *Rose diagram for cross-bedded sandstones from the braided alluvial plain.*

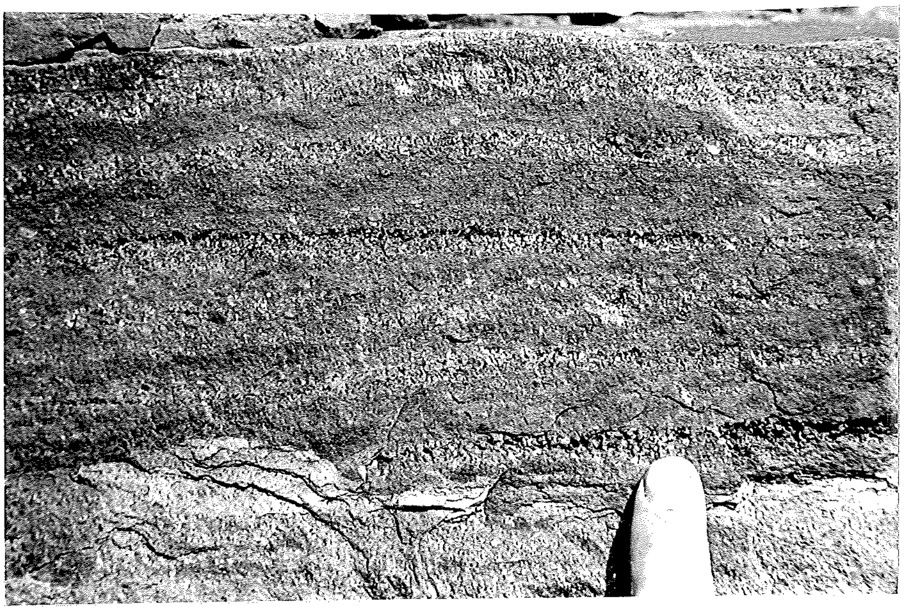


Figure 4 : *Graded horizontal laminae from the Mozaan fluvial deposits.*

these sediments indicates the presence of some free oxygen, but whether this was of biological or chemical origin is not clear. In terms of geometry and mineralogy, the Mozaan banded iron formation belongs to an oxide facies of the Algoman-type (Gross, 1966). This variety is characteristic of the Canadian Archean; however, in the Mozaan its association with shallow-water, as opposed to eugeosynclinal sediments indicates that it has affinities with the Superior-type. This has led

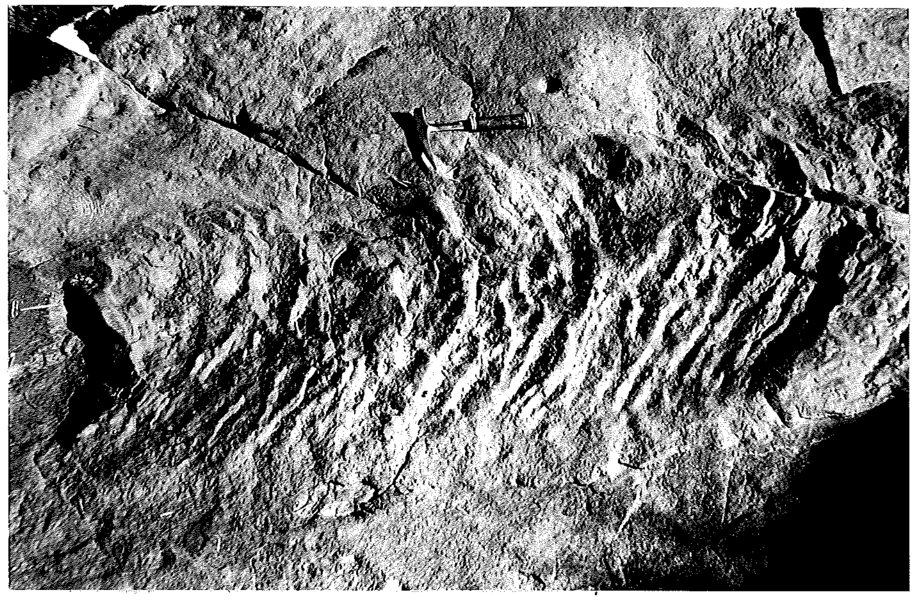


Figure 5 : Cross-cutting channels containing trough cross-beds from the braided-stream deposits.

R.W. Hutchinson (pers. comm., 1978) to suggest that the Mozaan banded iron formation possibly represents part of an evolutionary trend from the Archean to the Proterozoic. However, the poor development of the banded iron formation may be a function of a high rate of supply of clastic sediment. The restriction of these chemical sediments to the lower Mozaan stratigraphy indicates that exhalations from the underlying Insuzi may have been responsible for the fluctuations in redox conditions, as well as providing a source of Fe^{+2}.

Enveloping the banded iron formation is a sequence of black shales which may contain jasper or chert lenses and which, low in the stratigraphy, are often magnetic. The relation with the banded iron formation and the overlying facies suggests that these shales were deposited on a distal shelf controlled by simultaneous chemical precipitation and clastic fallout.

Gradationally overlying the shales is a sequence of up to 200m of interlaminated shales and rippled siltstones with occasional erosively-based sandstones. Trough cross-laminae and Jopling and Walker's (1968) sinusoidal and Type-B ripple-drift cross-laminae indicate the presence of gentle traction currents associated with pulses of rapid fallout from suspension. Interference ripples and polymodal ripple trends (Fig. 8) imply complex flow patterns probably modified by the subaqueous relief on a proximal shelf. The extreme thickness of these shelf deposits is ascribed to facies-stacking, whereby there is an intimate relation between sediment-supply and basin-subsidence. Coleman and Gagliano (1965) postulated that similar interlaminated muds and silts accumulated in the Mississippi delta in response to seasonal fluctuations in sediment input. The erosionally-based sandstones in this facies represent irregular high-energy events which may be attributed to storm activity, as suggested by

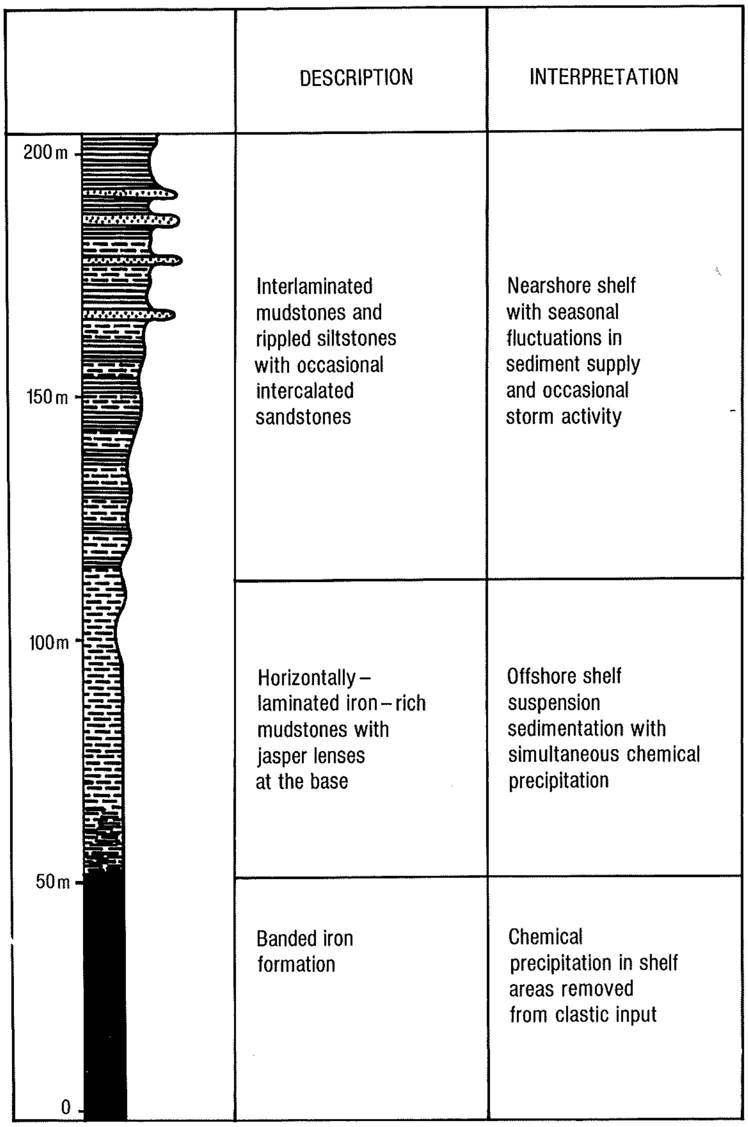


Figure 6 : Stratigraphic section and paleoenvironmental interpretation for the shelf deposits.

by Hobday and Reading (1972) and Kumar and Sanders (1976). The interlaminated shales are generally structureless, but display occasional sinuous scours, some of which contain a sandstone fill and runzel marks (Fig. 9). Klein (1977) is of the opinion that runzel marks provide good evidence for subaerial exposure. However, in view of the interpreted depositional environment, it is thought that these features must have developed in a similar fashion to that envisaged by Dzulynski and Simpson (1966) who attributed the wrinkling in turbiditic muds to the non-erosive shear produced by bottom currents. The association in this facies of shallow sandstone-filled depressions suggests a slight turbulence of the postulated bottom currents.

Figure 7 : Folded banded iron formation from the shelf assemblage.

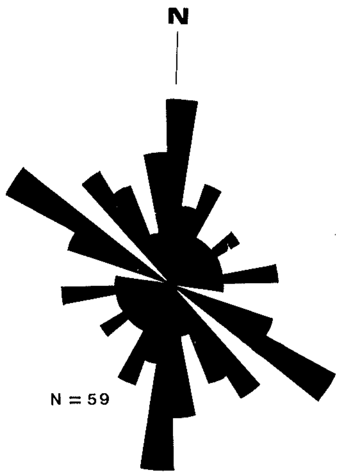


Figure 8 : Polymodal ripple trends from the proximal shelf sediments.

(c) Prograding Tidalites

When fully developed, the tidal sequence is similar to the upward-fining North Sea progradational model (Fig. 10) documented by Klein (1977). However, in the Mozaan Group, the heterolithic or mid-tidal-flat facies is generally poorly developed.

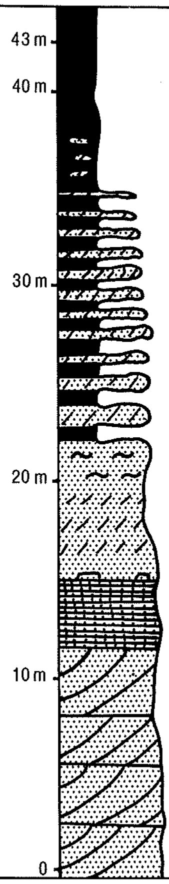
Quartz arenites, which gradationally overlie the proximal shelf, characterize the base of the tidal sediments. These sandstones are medium-

Figure 9 : *Runzel-marked shales with associated sandstone-filled scours from the proximal shelf deposits.*

to-coarse-grained and well-sorted and have well-rounded clasts. According to Balazs and Klein (1972), grain-rounding in tidal sandstones is due to extended transportation as the result of oscillatory tidal motion. However, having suggested a partly sedimentary provenance area for the Mozaan, texture and mineralogy are non-diagnostic properties. On the other hand, the association of a number of diagnostic sedimentary structures, accompanied by the typical upward-fining sequence, are highly suggestive of a tidal environment.

The upward decrease in grain-size and scale of sedimentary structures in the quartz arenites is similar to the B-C cycle described by Klein (1970b). The basal planar and trough cross-bedded B portion is 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 (Fig. 11) and belong to the C division of the cycle, synonymous with late-stage emergence runoff (Klein, 1971; Swett et al., 1971), thus distinguishing intertidal from subtidal areas (Hereford, 1977).

The cross-beds reflect unimodal southerly and easterly-to-northeasterly paleocurrents, in addition to bimodal oblique and weakly bimodal bipolar patterns. Assuming an east-west-trending coastline from fluvial paleocurrent data, it is apparent that tidal currents were oriented both basinwards and subparallel to the coast. The paucity of indicators of flood-tidal activity does not detract from a tidal regime, since several authors have documented a single mode in similar environments (Terwindt, 1971; Wright et al., 1975; Young and Long, 1977). This has been attributed to time-velocity asymmetry whereby a dominant tidal phase obliterates evidence of opposing flow directions (Johnson, 1975).



DESCRIPTION	INTERPRETATION
Horizontally laminated mudstones	Suspension sedimentation on high tidal mud flat
Lenticular bedding Wavy bedding Flaser bedding	Alternating bedload and suspension settling on an intertidal flat
Interference and flat-top rippled sandstones	Late-stage emergence runoff on intertidal sand flat
Plane-bedded sandstones	Wave swash on tidal sand shoal
Unimodal planar cross-bedded sandstones with occasional mudstone drapes	Migration of ebb-oriented sand waves in subtidal sand

Figure 10 : *Stratigraphic section and paleoenvironmental interpretation for the tidal assemblage.*

The poorly-developed heterolithic facies comprises interlaminated sandstones and shales, with the proportion of shale increasing upwards. This upward-fining is accompanied by a gradation from flaser-bedding, through wavy, into lenticular bedding at the top (Fig. 12). Reineck and Wunderlich (1968) described a similar sequence from the German mid-tidal flats, where they attributed its development to alternating bedload and suspension sedimentation during progradation. McCave (1970) was of the opinion that alternating storm and calm conditions are responsible for the lithologic interlamination, rather than individual tidal cycles.

Desiccation cracks, widely regarded as indicators of periodic emergence in early Precambrian shales (von Brunn and Hobday, 1976; Button and Vos, 1977; Eriksson, 1977) were not observed in the western Mozaan

Figure 11 : *Interference ripples with shale drapes from the low-tidal sand-flat.*

Figure 12 : *Lenticular bedding from the intertidal mixed-flat.*

basin. The reason for their apparent absence is not clear. However, numerous other studies of ancient intertidalites have similarily failed to note mudcracks (Klein, 1970a; Johnson, 1975).

Overlying the heterolithic facies are black massive or laminated shales which are interpreted as high-tidal-flat deposits. Larsonneur (1975) believed that sediment is introduced into such areas during high water and subsequently settles out of suspension. Occasional intercalated sandstones with erosive bases probably represent storm deposits (Reineck, 1975).

Klein (1971) speculated that, in progradational tidalites, the vertical thickness between the base of the low-tidal sand-flat and the top of the high-tidal mud-flat approximates the paleotidal range. Using this model, von Brunn and Hobday (1976) estimated that the paleotidal range in the southern Mozaan exposures was between 12m and 25m. The present study would concur with a macrotidal range, not only on the basis of the thickness of the tidal sequence, but also on the apparent absence of barrier sediments, since Hayes (1975) concluded that barriers are not developed in environments with tidal ranges exceeding 4m.

Scanty information is available regarding the development of linear tidal sand-bodies that parallel the coastline, other than that from the macrotidal Bay of Fundy, Newfoundland (Klein, 1970b, 1977; Knight and Dalrimple, 1975) and the North Sea (Reineck and Singh, 1978). From the Mozaan paleocurrent data, it is apparent that bedforms did migrate parallel to the depositional strike. Furthermore, the poor development of mid-tidal flats, such as in the Mozaan, is another characteristic of the Bay of Fundy. Consequently, it is suggested that two varieties of tidal sand-bodies were present within the Mozaan basin. The one type was dominated by southerly ebb-tidal currents and the other was the response to easterly-directed tidal currents. The latter flow direction might have been the result of the shape of the depository causing refraction of primary flood-tidal currents. The formation of tidal sand-bar complexes subparallel to the coast and the infrequency of mid-tidal-flat sediments are consistent with macrotidal sedimentation.

PALEOENVIRONMENTAL MODEL

From the interpretations of the constituent depositional models for the Mozaan Group, it is apparent that sedimentation was broadly controlled by the interaction of a braided alluvial plain with a macro-tidal marine basin. The absence of a recognizable deltaic sequence within the Mozaan is attributed to the effectiveness of tidal currents which redistributed available sediment at the fluvial/marine interface. In modern tide-dominated deltas, linear sand-shoals are constructed perpendicular to the coastline (Galloway, 1975). These sand-bodies display features consistent with deposition in a tidal environment and have associated intertidal and high-tidal flats (Coleman and Wright, 1975; Meckel, 1975). Therefore, it is suggested that progradation of such a system in the Mozaan produced a typical tidalite sequence and that fluvial influx was partly responsible for the tidal asymmetry. A similar model has been proposed for the deltaic members of the Proterozoic Shaler Group, Canada (Young and Long, 1977). Away from the areas of fluvial influence, it is postulated that sedimentation in the Mozaan was controlled by easterly-directed basinal currents of possible tidal origin (Fig. 13).

The offshore shelf sediments indicate that deposition was governed by an interplay between chemical precipitation and clastic sedimentation within a gently-subsiding basin. Occasional high-energy events, possibly related to either rip-currents or high fluvial discharge were responsible for intercalated coarse-grained sediments and may have resulted in localized scouring.

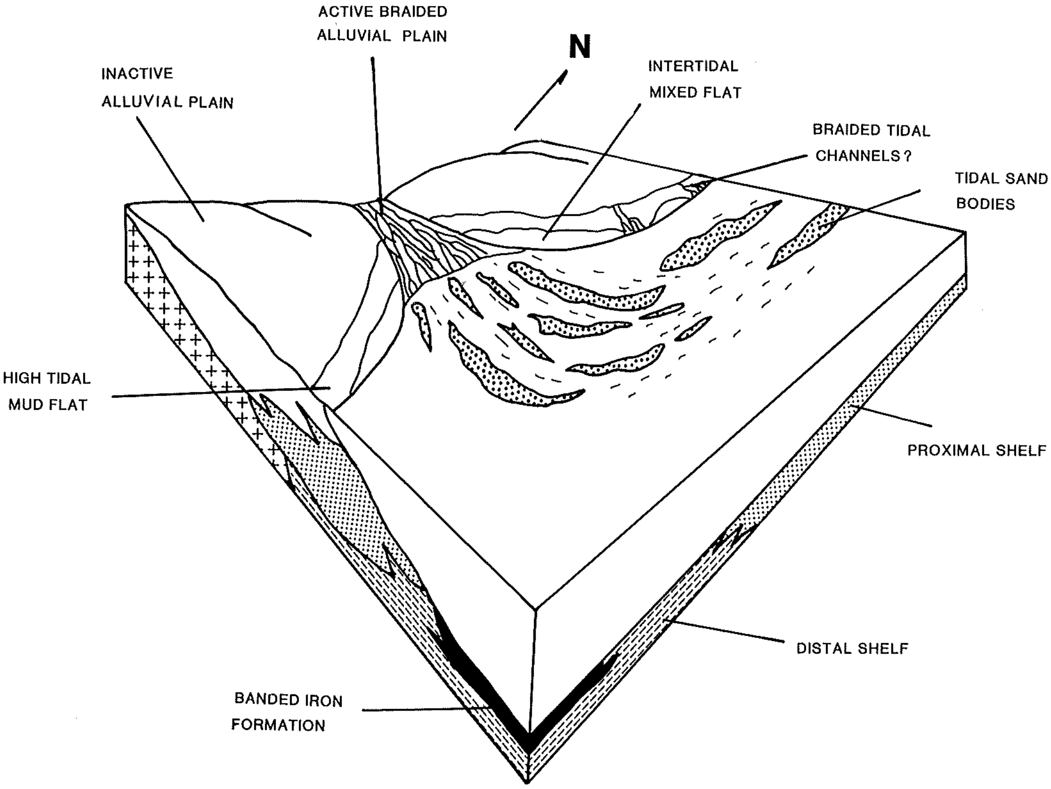


Figure 13 : Paleoenvironmental model for the western Mozaan basin.

CONCLUSIONS

In a North American or Australian context, the age of the Mozaan Group would place it within the Archean. However, Hunter (1974) and Cloud (1975) have suggested that the Kaapvaal structural domain had attained a degree of stability by the time of the development of the Pongola Supergroup and that this volcano-sedimentary basin was related to the evolution of the Southern African Craton during the Proterozoic.

The shallow nature of the Mozaan depository is indicated by the absence of turbidites in the shelf assemblage. Assuming a constant earth-moon distance, and, since shelf-width is directly related to tidal range (Redfield, 1958), the macrotidal conditions in the Mozaan suggest that the basin was an inland-sea connected to an open body of water.

The maturity of the sediments in both continental and marine environments, in addition to the presence of only a distal alluvial plain, imply a gentle paleoslope and tectonic stability. This accords with the fact that basin subsidence was gradual relative to sediment-supply, thereby producing prograding and vertical accretionary deposits.

From the nature of the Mozaan sediments and their interpreted environments of deposition, it is concluded that they were laid down under stable conditions. Consequently, it is postulated that the Mozaan basin was intracratonic and, therefore, the oldest documented Proterozoic-type sedimentary basin in the world.

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