TECTONIC AND SEDIMENTARY EVOLUTION OF THE COASTAL BASIN OF TANZANIA DURING THE MESOZOIC TIMES

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ABSTRACT

The present paper reviews and updates the stratigraphy and tectonic evolution of the coastal basin of Tanzania during the Mesozoic times based on the interpretation of existing palaeontological and stratigraphical information and supplemented by recent fieldwork investigations by the author.

Tectonic events largely controlled the evolution of the coastal basin of Tanzania and the Indian Ocean. These included the Karoo rifting during Permo-Triassic, the break up of the Gondwana Supercontinent, which started with rifting in the Triassic period, the opening of the Somali basin in the Middle Jurassic, and the Cenozoic rifting along the East African rift system. The Karoo rifting created a zone of weakness that led to the fragmentation of the Gondwana Supercontinent.

The Early Jurassic continental sediments developed in the graben-like structure with occasional marine incursions reflecting ancient seaways on the ocean side. The early Middle Jurassic oolitic limestones developed along the shoreline forming the marine carbonate platform. During these times, the area was periodically under fresh water influence. During Bajocian-Bathonian times, the whole of Tanzanian coast was completely under marine conditions though restricted to shallow sea in which coral reefs could grow. It was during these times that a stable continental shelf developed. However, the stability of the shelf was later affected by the reactivation of the Tanga Fault pattern. As a result, the sediments from the provenance including the Bajocian-Bathonian coral reefs were reworked and transported by means of gravity flow and fluvial influence, and deposited in a fault controlled shallow basin at Msolwa to form sub-marine fans. From the Callovian to Kimmeridgian, the main facies included the transgressive low energy shale and septarian marls rich in fossils, particularly ammonites. During this period, an open marine environment was predominant. This transgressive episode was succeeded by a regressive phase during Lower Cretaceous in which sandstone deposits were predominant. The Upper Cretaceous transgressive sediments (shales and marls) lie unconformably over the regressive older deposits, marking the topmost part of the Mesozoic sequence in the study area.

INTRODUCTION

The Coastal Basin of Tanzania occurs at the southern tip of the Somali basin, which is connected to the Natal basin in South Africa through the Mozambique Channel (Blunt 1973). To the southeast, the Davie Fracture Zone that represents a right – lateral drift of Madagascar bound the basin. The western margin is characterized by the vertical faults extending from Tanzania, through Kenya, Somalia to Ethiopia (Fig.1). In Tanzania, these faults are represented by two major trends: NNE – SSW Tanga Fault and NNW-SSE *Lindi* Fault (Fig. 2). The two fault patterns distinguish two major sub-basins in coastal Tanzania: Selous –Ruvu-Tanga rift along which the NNE-SSW Tanga Fault is predominant and Ruvuma-Mandawa basin containing the NNW-SSE Lindi Karoo fault trend.

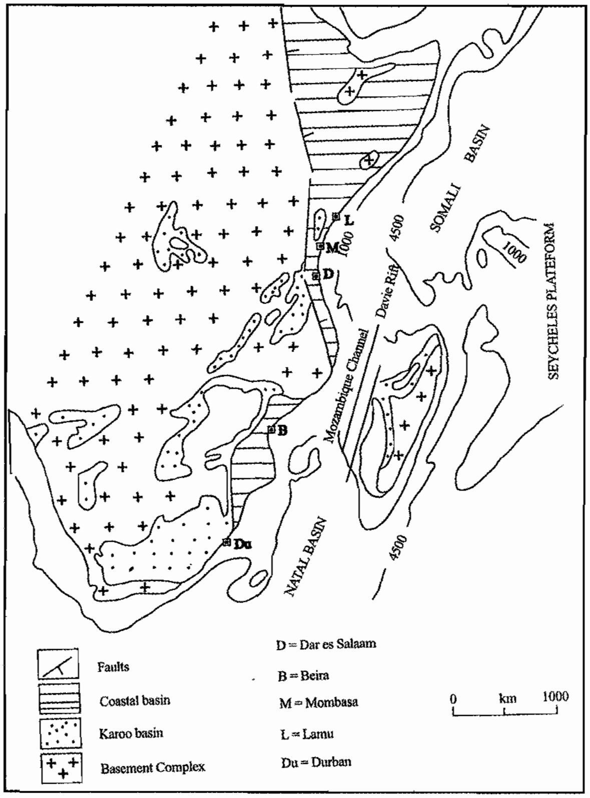

Figure 1: Sedimentary basins of East and South Africa, and Madagascar (modified from Blant, 1973)

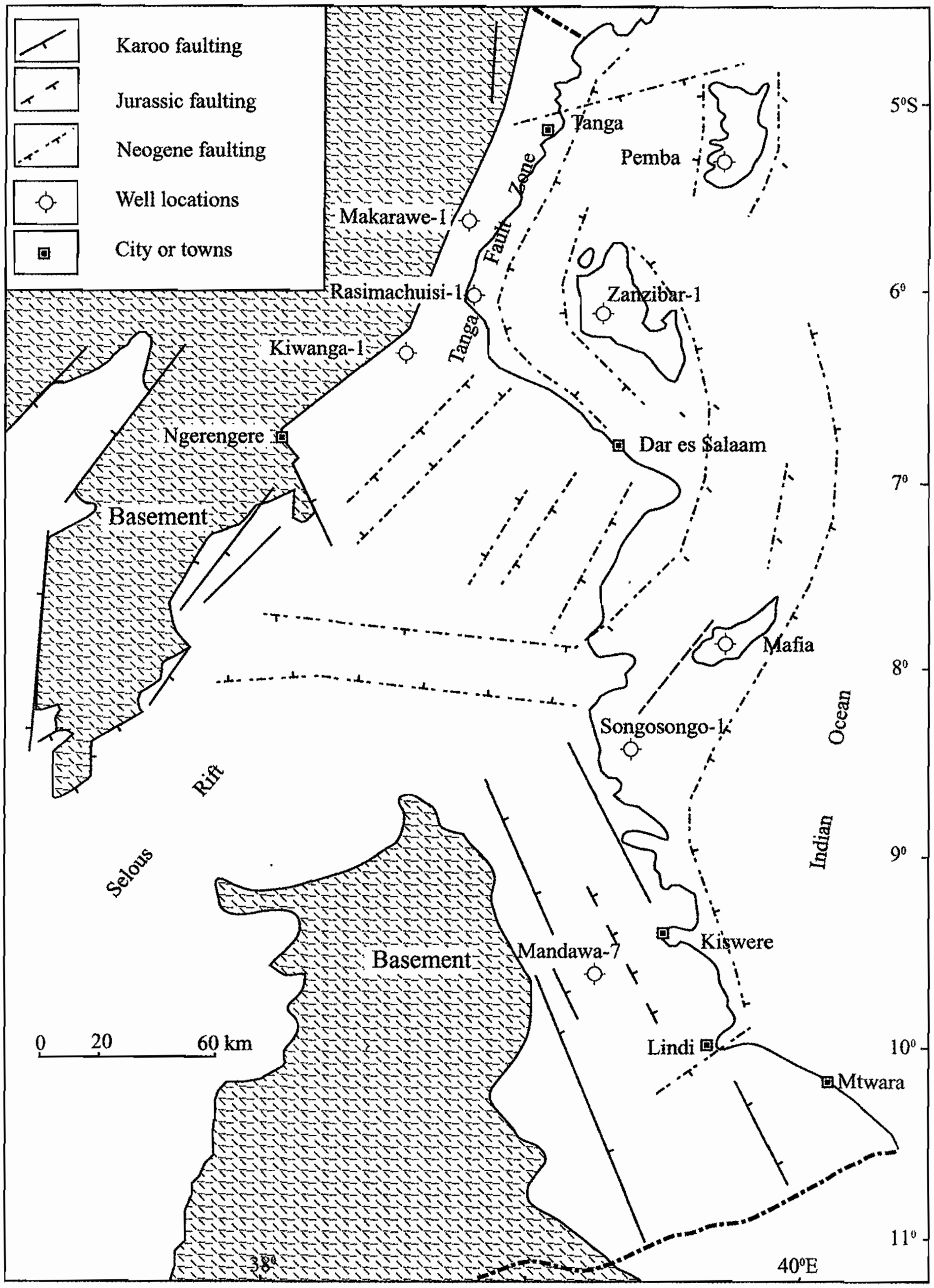

Figure 2: Major structural features of coastal Tanzania compiled from Kent *et al.* (Kajato 1982)

The opening of the Somali basin took place during Middle Jurassic times (Kent 1972). The opening resulted from the drifting apart of the Gondwana that started with rifting in Triassic (Windley 1986). Most of the tectonic movements which caused the fragmentation of the eastern Gondwana were vertical displacements related to extensional rifting and drifting (Rabinowitz *et al.* 1983) which facilitated the development of the present Coastal Basin encompassing a narrow belt along the mainland (Fig. 3). In Tanzania, the sedimentary bedrock column commences with the continental Karoo sequence, spanning in time from Permo-Carboniferous to Lower Jurassic. In the basins of Tanzania, this Karoo unit is represented largely by fluviatile arkosic sandstones to conglomerates and shales (Ngerengere - Formation) characterizing the Selous – Ruvu – Tanga rift sub-basin. However, in the Ruvuma – Mandawa sub-basin, marls and evaporitic sediments originating from restricted marine influence are included in the Karoo sequence and termed as Lower Pindiro evaporites (Anon. 1999).

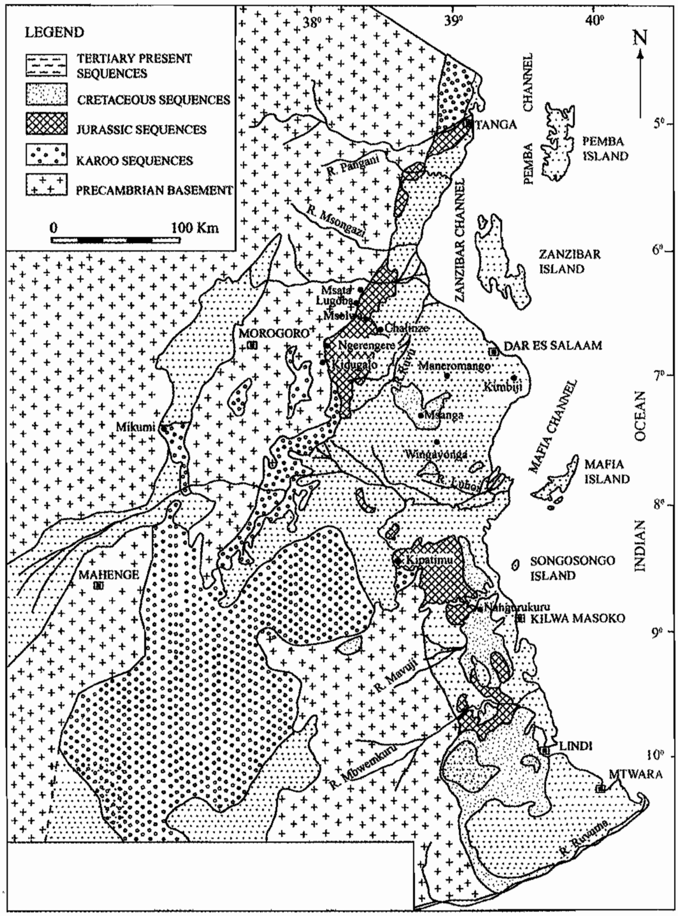

Figure 3: Geological map of coastal Tanzania compiled from Kent *et al.* (1971)

In the Middle Jurassic, a continental shelf was established with deposition of shallow water oolitic to oncolitic limestones of Aalenian age (Ruvu – Tanga fault sub-basin), detrital conglomeratic to coralliferous limestones of the Bajocian age and graded, detrital conglomeratic sandstones of post – Bajocian. These marine sediments are either overlying unconformably the metamorphic terrain in the vicinities of Msata and Lugoba or are separated from the basement complex by the continental sequence of the Karoo facies in the case of Tanga and Ngerengere (Kent *et al.* 1971). The marine transgression continued into the Upper Jurassic with deposition of shales, clay and ammonite-bearing septarian marls. From the Middle Jurassic to Cenozoic, several transgressions and regressions had occurred resulting into a thick accumulation of more than 4000 m and 6000 m of Mesozoic and Cenozoic sequences respectively. The present paper attempts a review and updates of the existing palaeontological, stratigraphical and structural information on the coastal basin of Tanzania in light of recent the field.

METHODS

Field investigations were conducted along the coastal basin of Tanzania from Tanga in the north, extending southwards to the hinterland of Kilwa and Lindi and involved systematic geological mapping of various lithological units. Where rocks were well exposed, stratigraphical profiles were also taken. Most of the exposures were along the roads, railway cuts and streams. On the basis of the lithological and palaeontological differentiation, the Mesozoic sediments in the study area were subdivided into a number of lithostratigraphic units as shown in Figure 5. The structural investigation involved measurements of attitudes of imbrication and slump structures, bedding planes, cross-laminations and beddings, fault and joint planes. The field observations were supplemented by the interpretative analysis existing data.

RESULTS

Stratigraphy and Sedimentation

Kajato (1982) has compiled the general stratigraphical successions of the sedimentary rock units in the whole of Coastal Basin of Tanzania (Fig.4). Following the recent lithological investigations by the author, the Jurassic sequence in the area has been renamed in accordance with more recent lithostratigraphical nomenclature as shown in Fig.5. The first onset of sedimentary rocks in Coastal Tanzania was marked by the deposition of the continental Karoo sediments. The sediments were mainly deposited in low relief areas and in a direct contact with the basement as well as with old faults which came to act as dividers between the sedimentary and metamorphic rocks (Kent *et al.* 1971). The deposition of the continental Karoo sequence was succeeded by the marine transgression, which embraced the entire Coastal Basin of Tanzania during Mesozoic times. It was during Bajocian period that the Coastal Basin of Tanzania became a carbonate continental shelf.

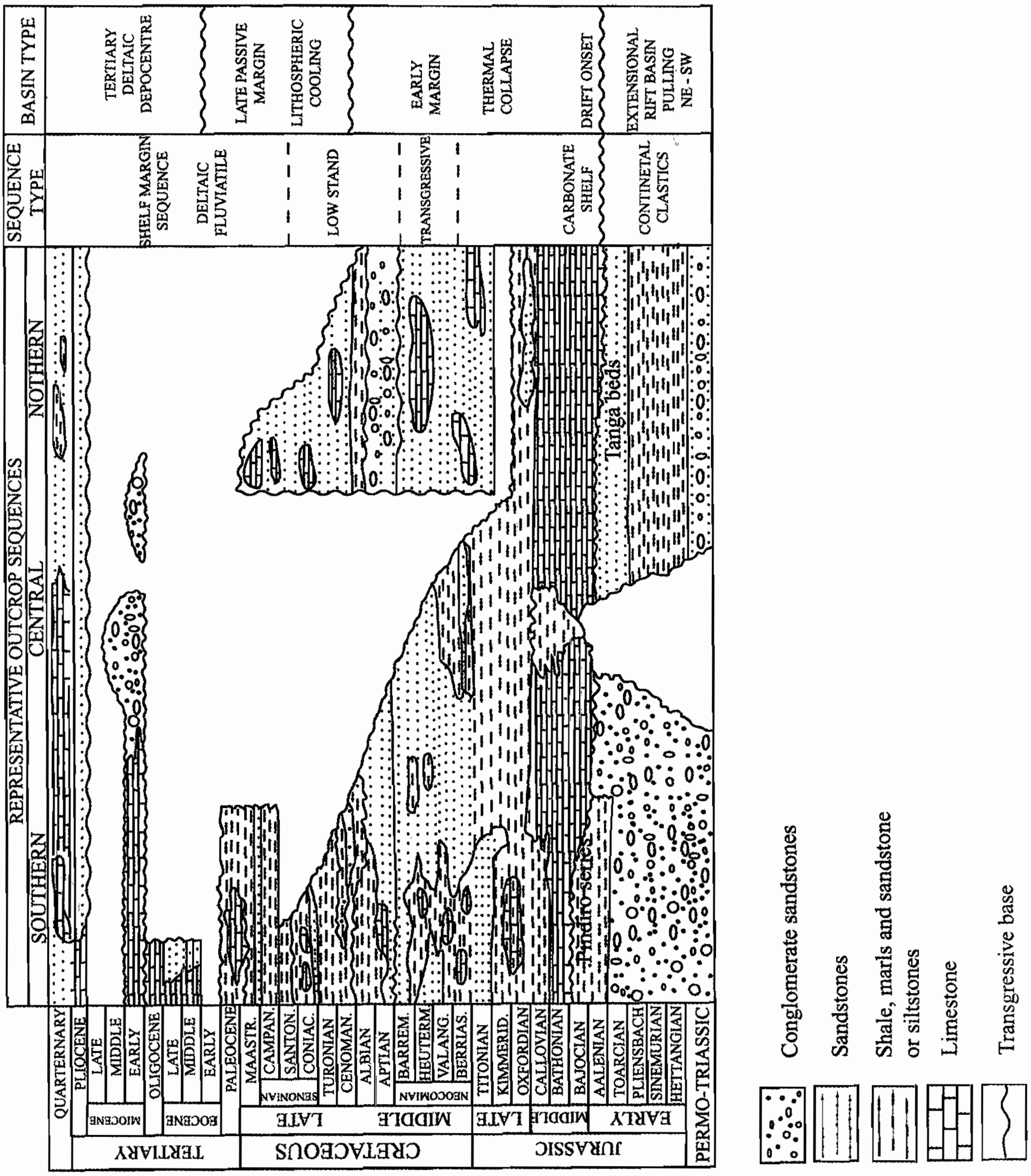

Figure 4: Generalized stratigraphy of coastal basin of Tanzania (Kajato 1982)

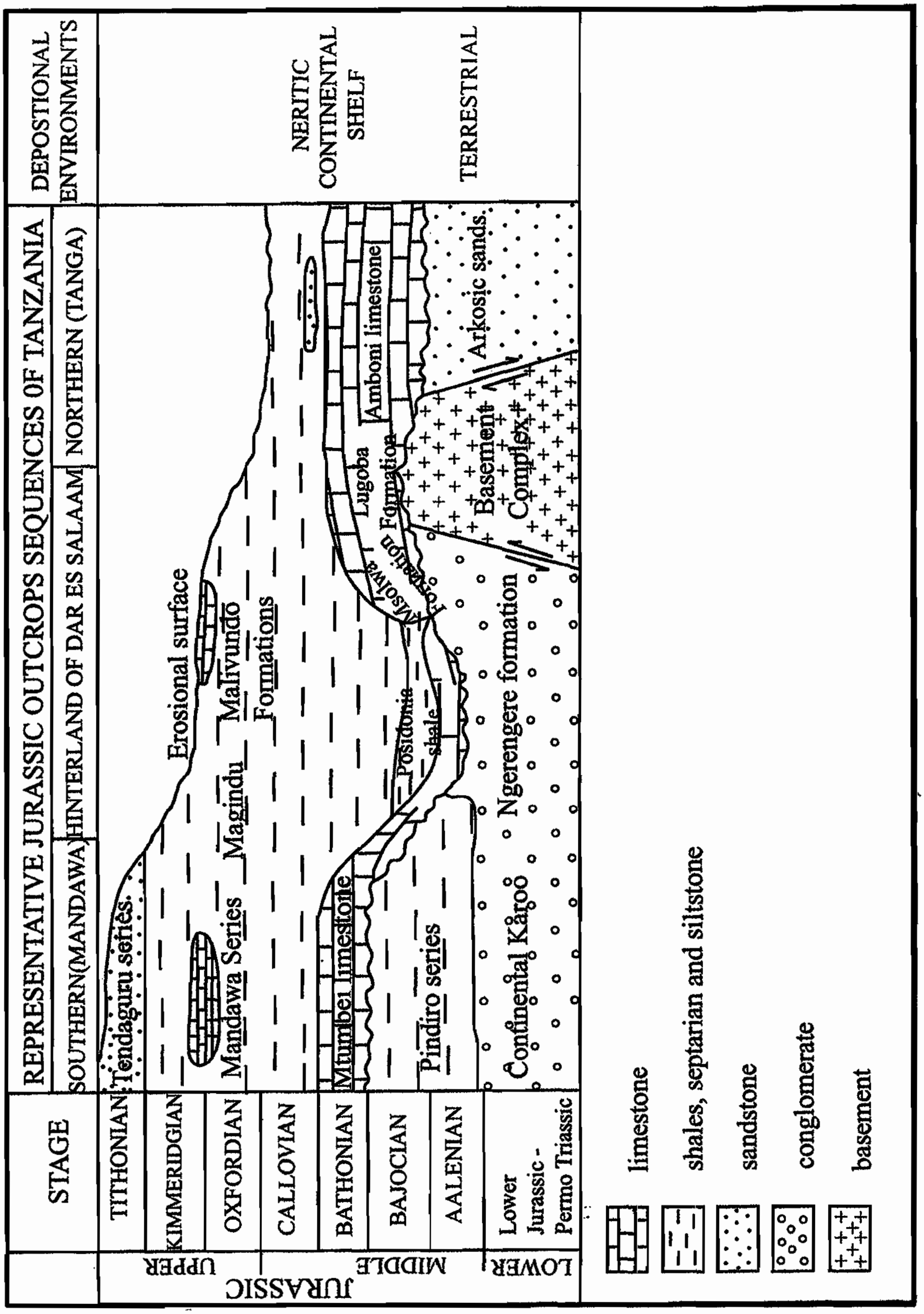

Figure 5: Schematic presentation of the Jurassic lithostratigraphic nomenclature

Karoo Sequence

The Triassic to Lower Jurassic sediments in the Coastal Basin of Tanzania consist of fluviatile arkosic sandstones which are of the continental Karoo origin. They unconformably overlie the basement complex in both sub-basins: Selous – Ruvu – Tanga Rift and Ruvuma – Mandawa. The tectonic structure accommodating these Karoo deposits was formed as a result of occasional subsidence followed by the down-faulted low relief depressions which were infilled with the clastic sediments (Mpanda 1997).

In the Selous – Ruvu – Tanga rift sub-basin, the sequence is represented by fluviatile arkosic sandstones and siltstones resting on basal conglomerates. These sediments around Tanga, have an eastward dip which increases from 5° to 10° inland to as much as 30°, at the coast. Total thickness of the sediments is about 2240 m (Kent *et al.* 1971). The same lithologic unit is exposed at Ngerengere with total thickness of about 760 m (Ngerengere Formation). In the Ruvuma – Mandawa sub-basin, a different depositional environment persisted whereby evaporitic sequence comprising gypsum, halites and anhydrite intercalated with silty shales developed to form Pindiro series (Nondwa – Formation). The lithofacies variation in the two sub-basins during this time interval reflects difference in rates of subsidence and sedimentary depositional environments. The evaporitic sequence developed in a very rapidly subsiding part of the basin, in which a restricted marine incursion took place. While, a complete sequence of the continental Karoo sediments accumulated in a very slowly sinking part of the basin (Mpanda 1997).

Middle Jurassic sequence

The stratigraphic interval corresponding to early part of the Middle Jurassic (Aalenian) is missing in many areas in the Coastal Basin of Tanzania (Fig.4). However, from the borehole at the vicinity of Kidugalo, Arkell (1956) described ammonite species from the Posidonia shale of Aalenian age. Kapilima (1984) also described ammonite species of Aalenian age from the marls sequence overlying the oolitic limestone at Kidugalo (Kidugalo – Formation). Associated with the oolites is occasional occurrence of gypsum suggesting sabkha environment (see Fig.6). Between Msata and Lugoba, the Bajocian sediments comprising detrital, conglomeratic limestone at the base and coralliferous limestone at the top (Lugoba – Formation) unconformably overlie the Usagaran basement complexes.

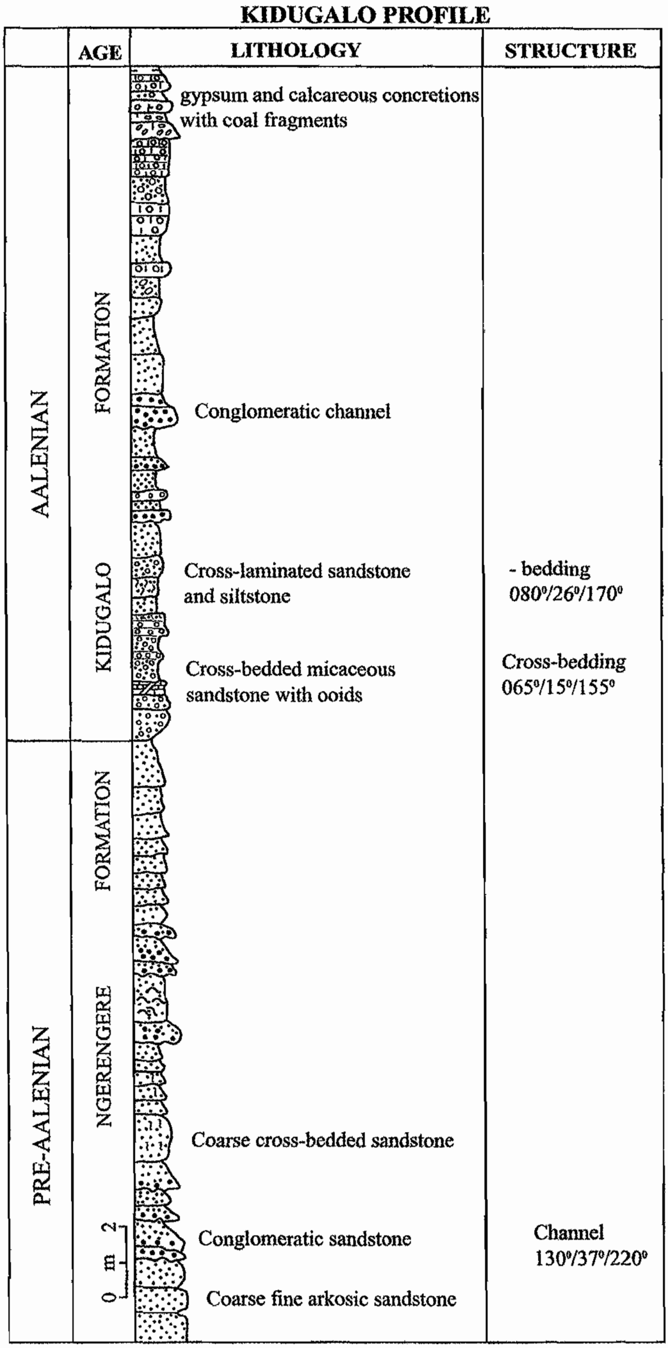

Figure 6: Middle Jurassic profile at Kidugalo, Tanzania

The Middle Jurassic sediments are also represented by the allochthonous, medium to coarse grained thick-bedded litharenites at the base and intercalations of fine grained, thin-bedded bioclastic sandstones and marls at the top (Msolwa – Formation). The sediments are probably of post-Bajocian. They rest unconformably on the red conglomeratic sandstone of the Karoo facies. In the Ruvuma – Mandawa sub-basin, the same lithostratigraphic unit (Mtumbei-Formation) overlies unconformably the continental Karoo red sandstone (Kent *et al.* 1971).

Late Jurassic Sequence
Between Callovian and Tithonian periods, a large part of the coastal basin of Tanzania was under the influence of neritic environment. The deepening of depositional environments is evidenced by the occurrence of more predatory marine organisms such as ammonites and nautilus. During these times there was much improvement of open marine influence as reflected by a large diversification of marine fauna including brachiopods and molluscans. The low energy depositional environments are suggested from thick accumulation of fine-grained deposits (mudstones, shales and marls) in the Mandawa and Ruvu basins.

Cretaceous Sequence
The Lower Cretaceous interval was marked by regressive phase, whereby continental red sandstones series was well developed in the Ruvuma – Mandawa sub-basin (Makonde-Beds). Fine to medium grained, cross-bedded, porous sandstone of Neocomian age crops out around Chalinze, which may be correlated to the gas-bearing sandstone at Songo Songo (Kipatimu – Formation). The correlation has been based on lithological similarities between the outcrop at Chalinze and borehole data from Songo Songo.The Middle Cretaceous unconformity and deposition of thick platform carbonates culminated the regressive episode and initiated another major marine transgression in the Late Cretaceous. This transgression led to the deepening of the ocean as supported by thick accumulation of clays rich in planktonic foraminifera in the Mandawa basin.

DISCUSSION

After the long interval represented by the metamorphism, uplifting and erosion of the Precambrian rocks of the Usagaran system, the East African Coast was much affected by the tectonic movements during Permo-Triassic periods (Kent 1972). Contemporaneously with the development of the Indian ocean (Rabinwitz et al. 1983), three tectonic events occurred along the present East African coast: Karoo rifting which affected the Tanzanian coastal areas during Permian (Kent 1972), the break up of the Gondwana continent which started with rifting in the Triassic (Windley 1986) and finally the opening of the Somali basin in the Middle Jurassic. The last tectonic event is the Cenozoic rifting along the East African rift system.

Karoo Rifting Phase
Along the Tanzanian coast, the Karoo rifting phase developed during Permian (Kent 1972). This episode was the first manifestation of sedimentary tectonic events affecting the whole region. The development of this Karoo rift proceeded and activated the extensional tectonics that resulted into the formation of NE-SW grabens (Selous – Ruvu – Tanga sub-basin) bounded to the west by the normal vertical faults (Tanga Fault) (Kent *et al.* 1971). The throw of the Tanga Fault is up to 6000 m (Kent *et al.* 1971). The initial opening of the Indian Ocean and fragmentation of the Gondwana might have been triggered by this phase. Two major intracraton faults including: The Tanga and Lindi faults together with Utete – Tagalala and Aswa Lineaments (Fig. 7, Kajato 1982) played a significant role in controlling the distribution and deposition of the continental

Karoo sediments in the varying lacustrine, fluvial and deltaic environments. These terrestrial sediments were largely deposited in these NE–SW trending grabens on the mainland as evidenced in Tanga, Mikumi, Ngerengere and Selous basin exposures (Furon 1963, Wopfener & Kaaya 1992). Similar geological and structural situations have been recorded along the western margin of the coastal basin of Madagascar (Kuprina & Maera 1989).

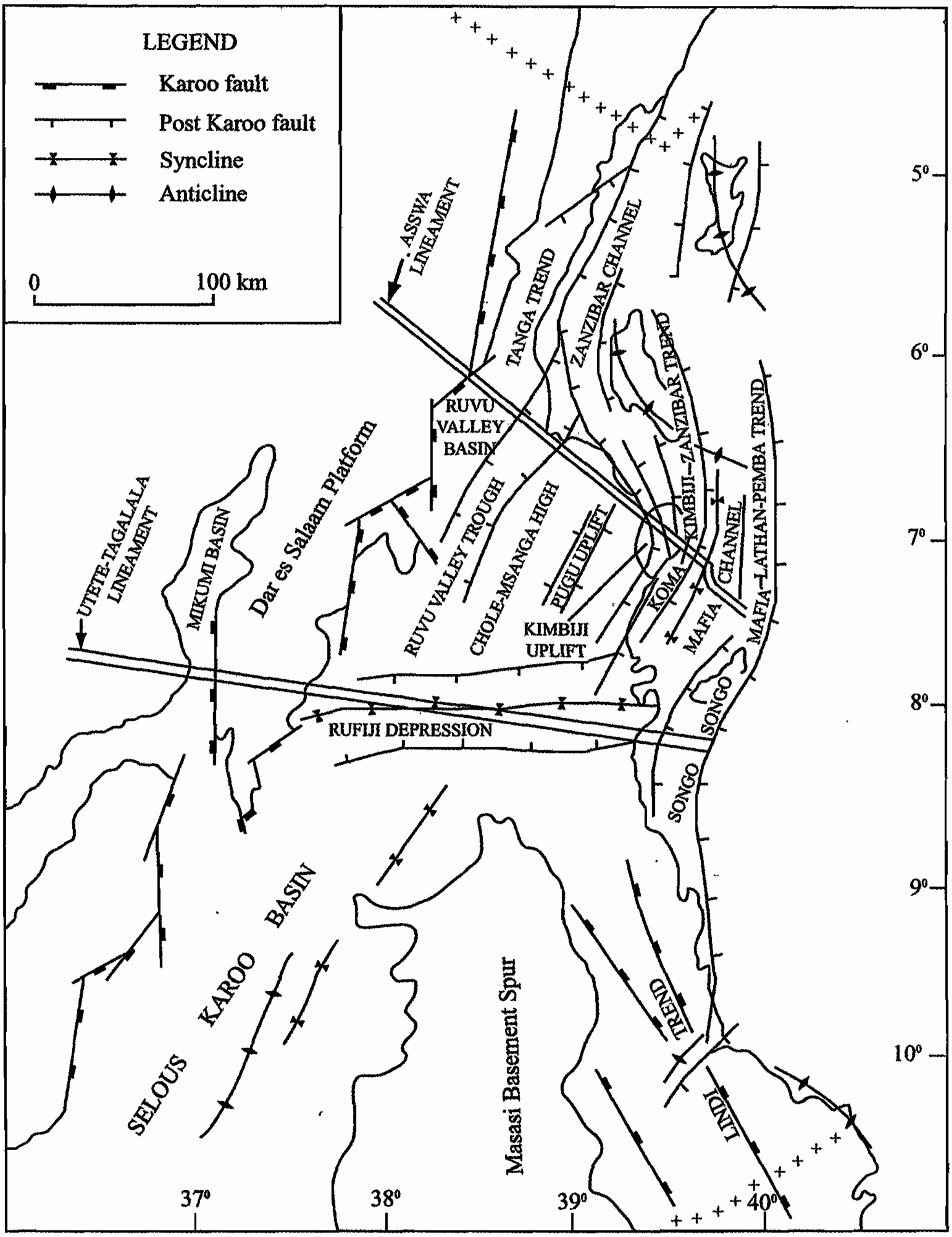

Figure 7: Structural style of the coastal Tanzania (modified from Kajato 1982)

The Break-up of the Eastern Gondwana

The Karoo rifting episode created a zone of weakness, which led to the breaking up of the eastern margin of the Gondwana. The rifting started in the Triassic, though the actual fragmentation did not start until in the Middle Jurassic and continued into the Early Tertiary (Windley 1986). By then, the Karoo basins were filled up with sedimentary continental rocks, and as separation of the continental plates increased, more and more marine waters transgressed into the old basins (Mpanda 1997). During these early stages of the fragmentation of the Gondwana there were only periodical marine incursions and differential uplifting. Such processes led to the formation of restricted depositions of marine sediments as evidenced in the Mandawa basin, where thick sequence of evaporites and shales of Triassic to Early Jurassic (Nondwa – Formation: formerly known as Pindiro evaporites – Anonymous 1999) accumulated. Likewise along the eastern coast of Kenya and the northwestern coast of Madagascar, Coffin & Rabinawitz (1987) have reported evaporites of the same age as that of Mandawa. In the Selous – Ruvu – Tanga Rift sub-basin, marine oolitic to oncolitic limestones with occasional occurrence of gypsum (Kidugalo - Formation and Amboni limestone) developed during this episode (Kapilima 1984). The widespread marine incursion in Tanzania occurred in the Bajocian times. It was during these times that the Somali Basin opened contemporaneously with the development of western Indian Ocean. This marine transgression covered the whole of the coastal basin of Tanzania from the Kenya boarder in the north, down to the Matumbi hills in the Ruvuma – Mandawa sub-basin (Kent et al. 1971). It was through this transgressive episode that carbonate continental shelf was established, being characterized by deposition of littoral coral reefs and coralliferous limestones with basal transgressive, detrital, conglomeratic sandstones (Kapilima 1984). The transgression overlapped a short distance westerly across the Tanga and Lindi faults onto the basement rock complexes. Besides the development of the coral reefs, there is clear evidence of the rejuvenation of the structural domains in the Coastal Basin during post-Bajocian times. At Msata, the reactivation of the Tanga fault is evidenced from the breciated underlying gneiss in which lithoclasts of siltstones, mudstones and limestones from the overlying coralliferous limestone (Bajocian) constitute about 2%. The breciated zone stretches in a NE-SW trending belt. Further evidence of this kind of rejuvenation is observed at Msolwa quarries where thick and thin-bedded grey detrital conglomeratic and bioclastic sandstones intercalated with marls developed as sub-marine fans. The Msolwa sediments are largely coarse grained, graded sandstones to detrital limestones at the base and the intercalations of calcareous siltstones and marls at the top. The sedimentary structures such as a graded-bedding (coarse to fine at the top), thick – and thin-beddings, imbrications, scratch marks and slumping suggest allochthonous nature of the sequence. It is postulated that accumulation of such sequence was a result of a down slope resedimentation of unstable coral reefs (Lugoba – Formation) and basement complexes. It is evident that, the Tanga fault was active during the formation of the sequence. The sediments from the provenance appear to have been transported by gravity flow under fluvial influence, and deposited in a fault controlled shallow marine basin at Msolwa as submarine fans (Fig. 8).

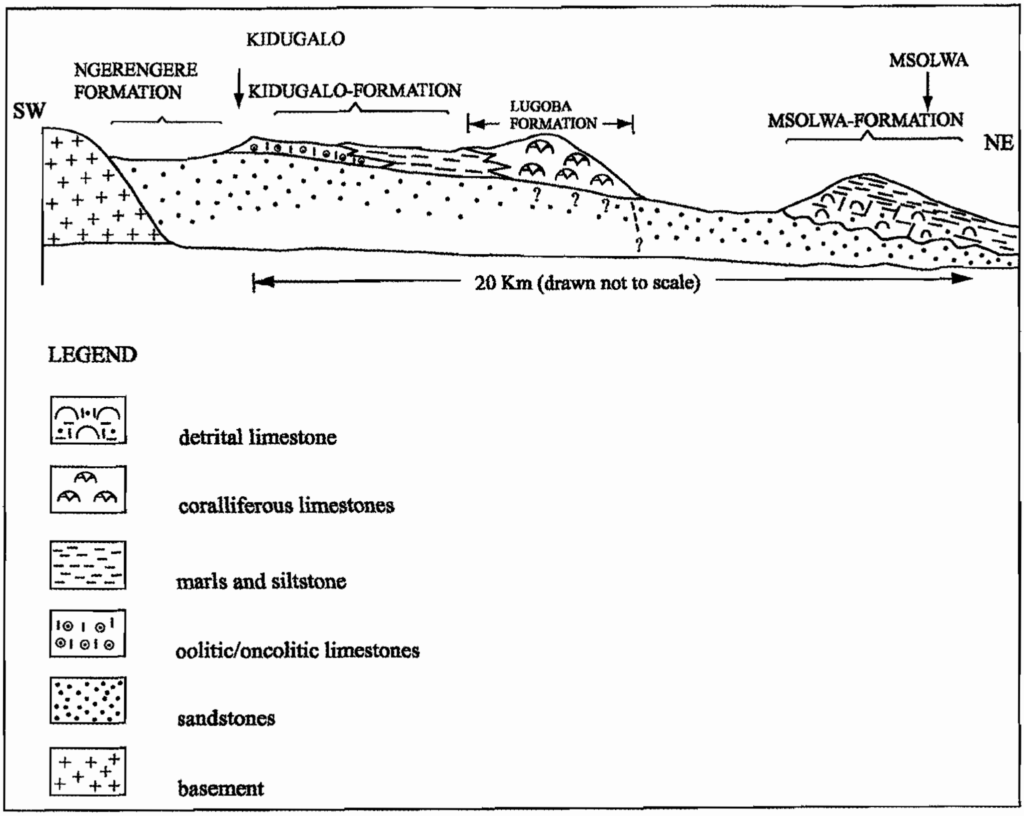

Figure 8: Kidugalo – Msolwa sketch with Msolwa sub-marine fan, Tanzania

The Middle Jurassic transgression continued into the Upper Jurassic times, where neritic environments prevailed. The sediments are characterized mainly by ammonite-bearing septarian marls. The Lower Cretaceous interval was marked by a regressive episode which was presumably controlled by world wide eustatic movements and partially associated with an end of Jurassic – Early Cretaceous phase of faulting (Kent *et al.* 1971). Continental red sandstones (Makonde Beds) particularly in the Ruvuma – Mandawa sub-basin, therefore represent a large part of the Lower Cretaceous. The regressive episode was followed by the Aptian-Albian transgression that was controlled by the major old fault trends of Tanga and Lindi. The Late Cretaceous is largely characterized by marine transgression with accumulation of clays, marls and sandstones rich in foraminifera.

ACKNOWLEDGEMENT

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