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SHALLOW-WATER DEPOSITS WITHIN THE BURUNDIAN PROTEROZOIC (REPUBLIC OF BURUNDI, EAST-AFRICA)

by Roland DREESEN (*)

ABSTRACT. - For the first time an environmental approach is made for some selected low-grade metamorphic quartzitic sequences attributed to the (Upper-) Burundian (Kibaran-Karagwe-Ankolean) of northern Burundi (East-Africa). Petromict conglomerates and rhythmic subgreywackes on top of the Nile-Zaïre watershed, W of Kayanza, are interpreted as fanglomerates and alluvial sandstones.
Fine-grained and rhythmically laminated quartz arenites N of Ngozi may represent a regressive intertidalite with a well-preserved lower sand flat and a mixed flat environment.
A sequence finally, within the Burundian type-area W of Muyinga, composed of alternating quartzites and shales, is attributed to slight transgressions and regressions of a tidal sea; different near-shore subenvironments are recognized : beach sands, upper-offshore (coastal sand-shelf mud transitional area) and backshore with tidal inlets.
From these case-studies we may conclude that there is persistent evidence for shallow-water deposition during the (Upper-) Burundian (Mid-Proterozoic) in the Republic of Burundi and that these conditions are not dissimilar at all from equivalent modern environments.

INTRODUCTION

The Burundian Supergroup (belonging to the Mid-Proterozoic Karagwe-Ankolean metamorphic belt) consists essentially of alternating quartzitic and phyllitic sequences. Cross-laminated and parallel-bedded quartzitic formations were already observed within microconglomeratic and coarse-grained quartzitic sandstones of the Upper-Burundian Group (WALEFFE, 1965), but nothing has been written until yet about the depositional environment of these quartzitic formations.

Near the northern extremity of the Kibaran-Karagwe-Ankolean belt, south of Lake George (Uganda), bodies of conglomerate and quartzite have been interpreted as delta-fans laid down by rivers flowing of the foreland (READ & WATSON, 1975, p. 115).

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Actually "Aangesteld Navorser bij het Nationaal Fonds voor Wetenschappelijk Onderzoek".

Coarse conglomerates at the top of the Nile-Zaire watershed in Northern Burundi were erroneously interpreted as glaciogenic deposits (ANTUN, 1961; CAHEN & LEPERSONNE, 1967). In the present paper an attempt has been made to reconstruct the environment of deposition of some quartzitic sequences attributed to the (Upper-) Burundian. Some selected sections within three quartzitic sequences attributed to the (Upper-) Burundian in Northern Burundi (sheets Ngozi S3-29 SE and Muyinga S3-30 SW) (see figs. 1 and 2) were recently studied by us and for the first time, an environmental interpretation based on the observed primary sedimentary structures is given. Because of the lack of a detailed and the non-availability of a general lithostratigraphical scale for the Burundian Supergroup, no lithostratigraphical correlation has been made between the different studied sections. Nevertheless we may consider them as to be deposited within a same stratigraphical interval, which is either an upper part of the "Burundian" or a new Proterozoic low-grade metamorphic belt, possibly the equivalent of the "Itombwe Supergroup" of Eastern Kivu (Zaire).

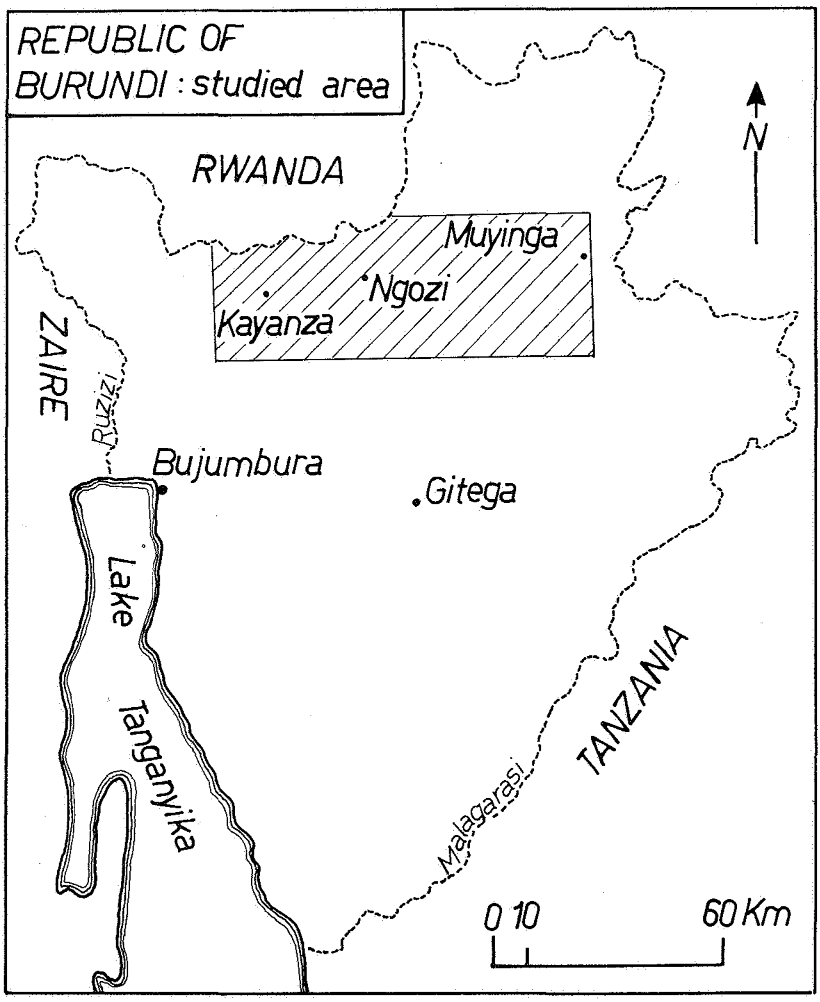


Fig. 1 - Studied area within the Republic of Burundi.

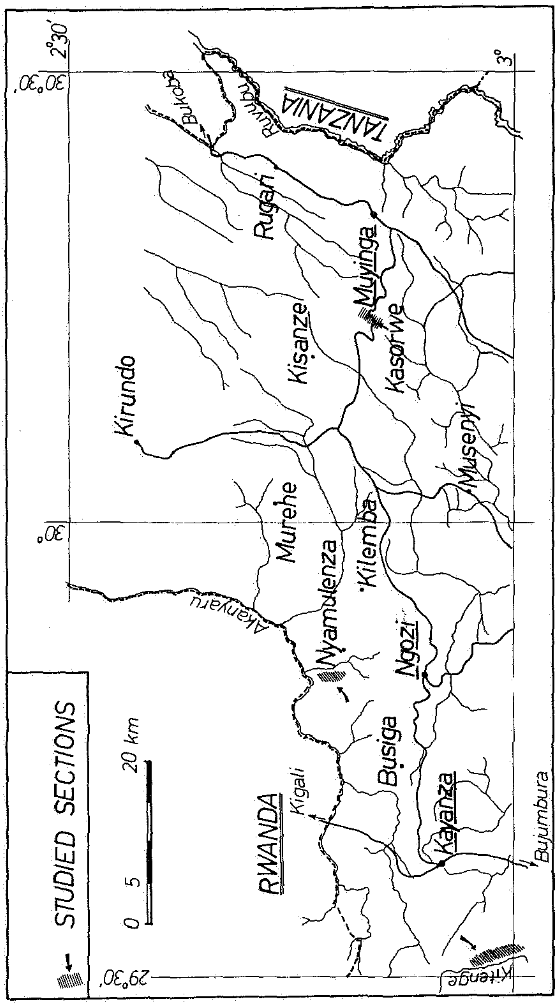


Fig. 2 - Location map of studied sections in northern Burundi.

GEOLOGICAL SETTING - STRATIGRAPHY.

The Republic of Burundi territorium is situated on the eastern uplift of the western branch of the East African Rift System. Except for the Meso (?)- Cenozoic alluvio-lacustrine sediments filling up the Tanganyika Graben and some recent basaltic lavas partially covering those deposits in the northern part of the Ruzizi plain, the subsoil of Burundi consists of metamorphic and magmatic formations of Precambrian age.

They belong to the so-called Central African Metamorphic Belt - extending from the Equator to the 15° Southern Parallel, along the 30° Eastern Meridian - developed between two stable older Precambrian Cratons : the Congo Craton and the East-African Craton. This folded metamorphic belt (see fig. 3), characterized by a polycyclic geologic evolution of its metamorphic constituants - the early Proterozoic Ubendian-Ruzizian belt and the Mid-Proterozoic Karagwe-Ankolean-Burundian belt - represents a well-individualized structural unity with respect to the surrounding Archaean Cratons.

Different orogenic paroxysms successively affected the sedimentary and magmatic formations accumulated in the Precambrian "geosynclines" and/or intracratonic basins : the Ruzizian-Ubendian cycle, the Kibaran-Burundian-Karagwe-Ankolean cycle and the late-Proterozoic Katangan cycle.

Initially, the Precambrian of Rwanda and Burundi was lithologically subdivided into two major unities (Supergroups) : the "Burundian" (greenschist facies) and the "Ruzizian" (amphibolite facies) (DELHAYE & SALEE, 1928). A third, non-metamorphic unity, the Malagarasian, recognized by DELHAYE, SALEE in CAHEN (1954) and refined by WALEFFE (1965), represents a late-Proterozoic cover-formation along the Burundian-Tanzanian border.

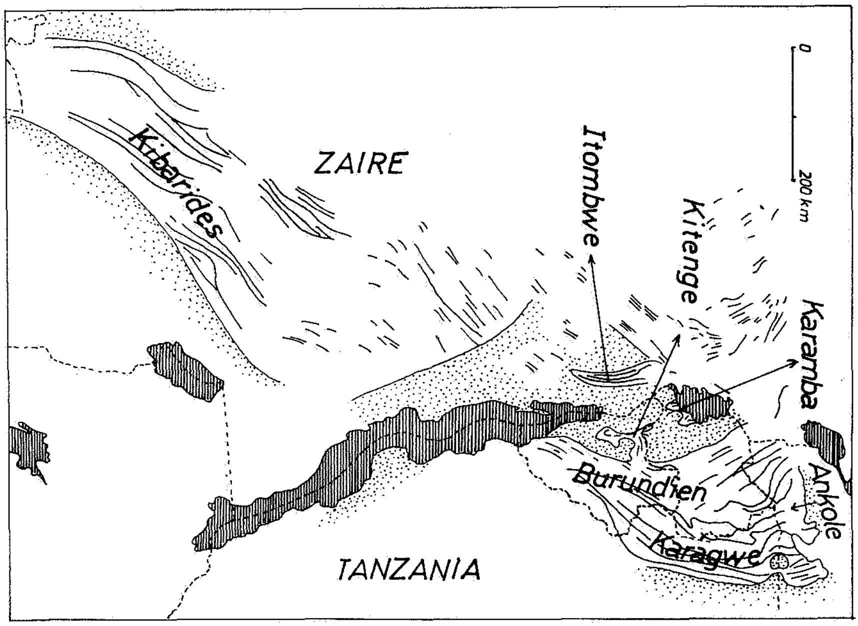


Fig. 3 - Tectonic sketch map of the Kibaran-Burundian-Karagwe-Ankolean mobile belt (after CAHEN & LEPERSONNE, 1967).

Stromatolitic assemblages in the dolomitic limestone formations of the Mutsindozi Group indicated an Upper-Riphean age for the Malagarasian deposits (Bertrand-Sarfati, 1976).

The Burundian consists essentially of low grade metamorphic rocks of pelitic and arenaceous origin; conglomerates and grits are much less abundant. The Ruzizian consists of a wide variety of middle-grade metamorphic rocks such as metaquartzites, sericitoschists, micaschists, gneiss, amphibolites and metamorphic limestones.

Recently, different lithological facies were recognized within the Ruzizian, and some high-grade polycyclic metamorphic rocks (subgranulite facies), formerly attributed to the Ruzizian, are now to be considered as Archaean basement spots (fringe area of the Eastern African Craton) protruding through their Proterozoic cover (KLERKX & THEUNISSEN, 1977).

The Burundian rests unconformably on the Ruzizian, which is traversed by granites or pergmatites, about 1,850 Myr old, which have not affected the Burundian, for which numerous granites, pegmatites and veins have yielded ages between 1,300 Myr (syntectonic) and 845 Myr (postorogenic) CAHEN & LEPERSONNE. 1967).

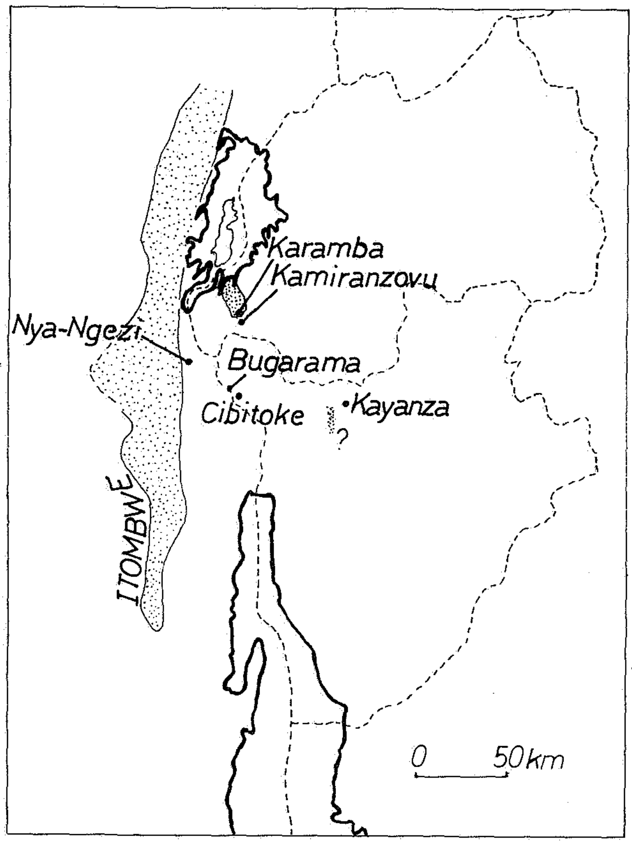


Fig. 4 - Location map of sedimentary formations related to the Itombwe Supergroup (after Villeneuve, Frautschi, and others, 1976).

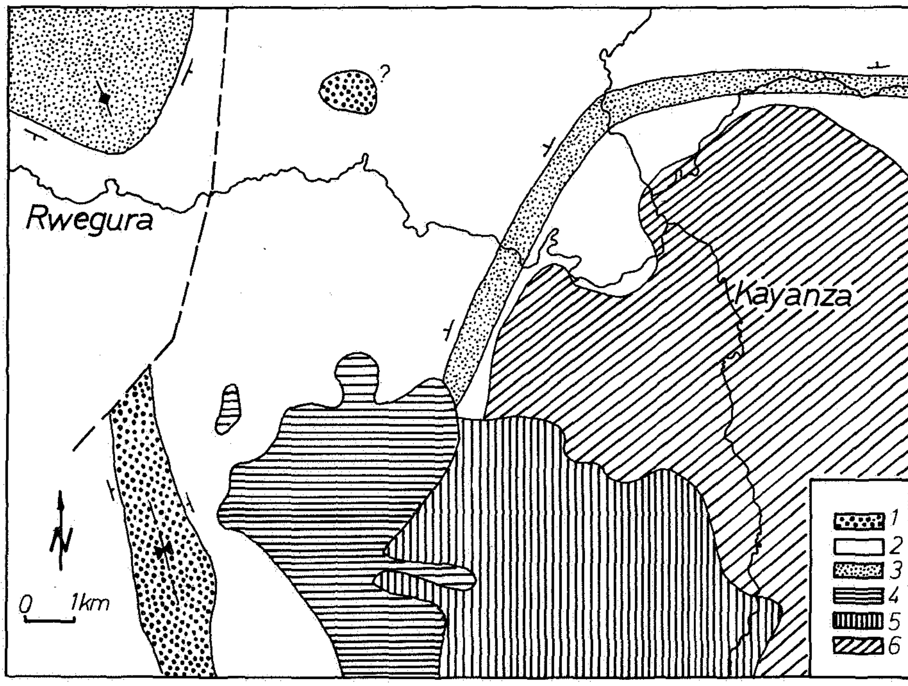


Fig. 5 - Geological sketch map of the Kayanza area (after Archives of the Dept. Geol. Mineral., Mus. roy. Afr. Centr., Tervuren, Belgium).

Legend : 1 - Mikiko formation
2 - black and green phyllites including metavolcanic rocks
3 - metaquartzites (2+3) : the so-called "Bugarama"-Group)
4 - basic alcaline complex
5 - nepheline syenite
6 - granitoïds

A local threefold lithostratigraphical subdivision of the Burundian Supergroup was proposed by WALEFFE (1965) for eastern Burundi.

The Lower-Burundian Group consists essentially of alternating phyllites, quartzitic phyllites and banded quartzites with minor phyllitic intercalations. In the basal part coarse-grained quartzites and conglomeratic facies occur (thickness estimated at + 10.000 m).

The Mid-Burundian Group consists of shales, sandy shales with quartzitic intercalations, and well-stratified quartzites (Muyinga Quartzites) with minor shaly intercalations (thickness ± 2.500 m).

The Upper-Burundian Group consists of shales, sandy shales, microconglomeratic quartzites with frequent crossed bedding (Kahororo Quartzites) and ferrugineous quartzites (Kameramogambo Quartzites) with minor shaly intercalations (thickness estimated at + 1.350 m.).

Since no or only minor structural and metamorphic characteristics were taken into account, the value of the former twofold (Ruzizian-Burundian) and threefold (Burundian Supergroup) subdivision has become questionable. Indeed, detailed tectono-metamorphic and petrographic investigation (by the Department of Geology-Mineralogy of the Musée Royal de l'Afrique Centrale, Tervuren (Belgium) pointed out that at least a part (the Lower-Burundian Group ?) of the Burundian Supergroup represents in fact a lower metamorphic facies of the underlying Ruzizian. Further on, the uppermost (conglomeratic) quartzitic levels of the Burundian, show close lithological affinities with analoguous coarse-grained formations of the "Itombwe Supergroup"; this Upper-Proterozoic belt, recently recognized in Eastern Kivu (Zaîre) has been deposited between 1,310 Myr and 648 Myr (CAHEN, LEDENT & VILLENEUVE, 1979) (see fig.4).

LITHOLOGICAL DESCRIPTION AND ENVIRONMENTAL INTERPRETATION OF SELECTED SECTIONS WITHIN "BURUNDIAN" QUARTZITIC SEQUENCES.

I. THE KITENGE RIVER area W of KAYANZA :

On the watershed W and SW of Kayanza, the so-called Nile-Zaîre ridge, conglomeratic formations were described for the first time by ANTUN (1961 unpublished, and 1964). The conglomerates occupy the heart of a NS-oriented synform, which is essentially composed of green and grey-black phyllites (the so-called "Bugarama"-Group, uppermost Ruzizian ?) enclosing basic and acid metavolcanites in their basal part (see fig. 5).

Some of the conglomeratic formations studied by Antun and described by him as "schistes à blocaux" (shales with boulders), were later considered by CAHEN & LEPERSONNE (1967) as "tilloids" or "mixtites" (with a questionable glaciogenic origin). The same authors made a stratigraphical correlation between these conglomerates and analoguous coarse-grained formations from the "Itombwe Synclinorium" of eastern Kivu (Zaîre).

PEETERS (1956) recognized analoguous conglomeratic formations in Rwanda and considered them as Burundian deposits. ANTUN (1965) correlated the conglomeratic formations of the Nile-Zaîre ridge with the Miyove Series" of Rwanda (GERARDS & LEPERSONNE, 1964), which correspond to the Upper-Burundian Group of eastern Burundi (WALEFFE, 1965).

CAHEN, LEDENT & VILLENEUVE (1979) finally dated the "mixtites" of the Itombwe-area as post-Burundian.

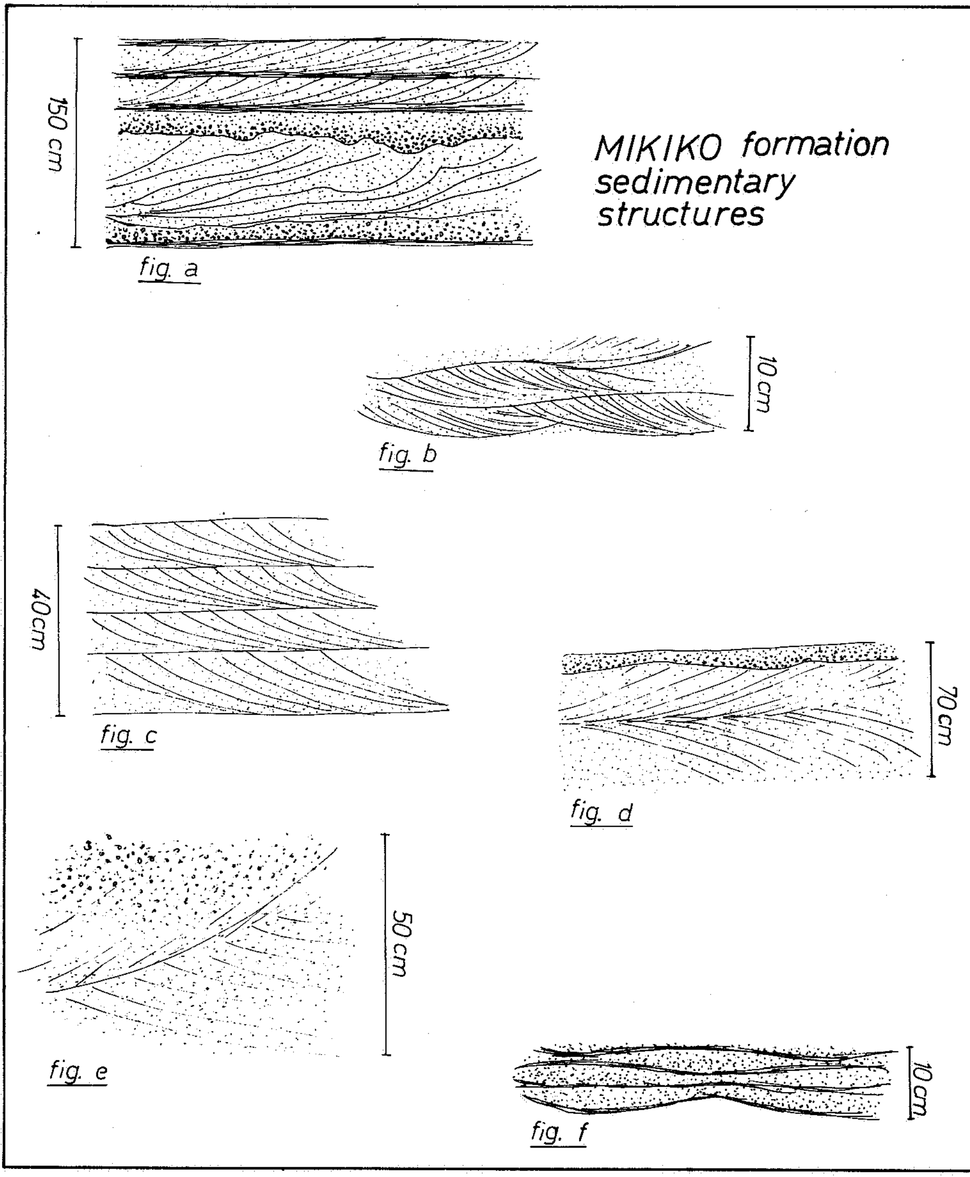


Fig. 6 - Sedimentary structures observed within the "coarse-grained rhythmic sequence" of the Mikiko Formation :

a - cosets with lateral changing dip of a cross-stratified unit, eroded by a gravelous sand layer.
b - micro cross-laminae in fine-grained quartzitic sandstone.
c - cross-bedded sequence in coarse-grained sandstones.
d - herringbone cross-stratification unit eroded by a microconglomeratic layer.
e - herringbone cross-stratification within a coarse-grained sandstone displaying reverse graded bedding.
f - lenticular bedding (lenticular coarse-grained sandstones and greyish phyllitic shales).

The conglomeratic sediments at the top of the Nile-Zaîre watershed ridge SW of Kayanza, named here the Mikiko formation (after the Mikiko hill type locality, + 2.500 m), are composed of a rather coarse basal conglomerate and an important coarse-grained quartzitic rhythmic sequence.

Because of the presence of numerous NS-oriented faults (frequently quartz-filled within the latter sequence, only a rough estimation of its thickness can be made : between 12 m and 20 m for the basal conglomerate; up to 200 m or more for the rythmic sequence.

Lithologically, the basal conglomerate is a poorly-sorted and medium-rounded polymict conglomerate. It is mainly composed of flattened whitish medium- to fine-grained quartzite pebbles and limpid vein quartz pebbles (average diameter 5 to 10 centimeters; locally up to 30 centimeters) in a dark-grey pelitic matrix, mineralized by ironoxydes.

Minor constituents are greenish-grey phyllitic shales, black tourmalinites and some rare weathered metavolcanic (?) rock fragments.

Except for the preferential orientation paralled to stratification of the phyllitic detritical elements and an indistinct graded bedding, no primary sedimentary structures are observed.

The surmounting coarse-grained quartzitic sequence is composed of rhythmically alternating - mainly in beds of 0,5 to 1 m - lithic greywackes, litharenites, psammoshales and quartzites. Their major detritical components are angular quartz (often rosy glassy quartz), small rock fragments (mainly phyllitic) and muscovite.

The matrix is essentially sericitic with fine quartz and locally abundant magnetite octahedrons.

Cross-bedding is very frequent (see fig. 6); within a cross-bedded unit sudden lateral changes in dip of the foresets may occur. Reverse grading is also frequent and appears to be often associated with herringbone cross-stratification.

In the fine-grained quartzitic levels some "ball-and-pillow" structures were recognized (pseudonodular sandstone bodies).

The microconglomeratic (subgreywackeous) layers which are mostly lenticular-shaped, show scoured lower surfaces (erosional unconformities.

ENVIRONMENTAL INTERPRETATION.

In our opinion there is persistent evidence for shallow-water deposition of the sedimentary formations mentionned.

By their particular nature (coarseness, poor sorting and rounding, great diversity of their detrital components, rhythmicity, important matrix content) and by the presence of some characteristic sedimentary structures such as reverse grading, cross-bedding with changing dip of the foresets, these coarse-grained and conglomeratic sediments must be interpreted as laid down by rivers draining a mountainous region with marked fresh topography, which contributed the fresh lithic elements. We have no definitive arguments to differentiate alluvial plane from deltaic environments, although the numerous eroding microconglomerates indicate probably subaerial deposits.

The basal conglomerate of the Mikiko Formation is thus interpreted as a fanglomerate; the surmounting "coarse-grained rhythmic sequence" is interpreted as a series of alluvial sandstones.

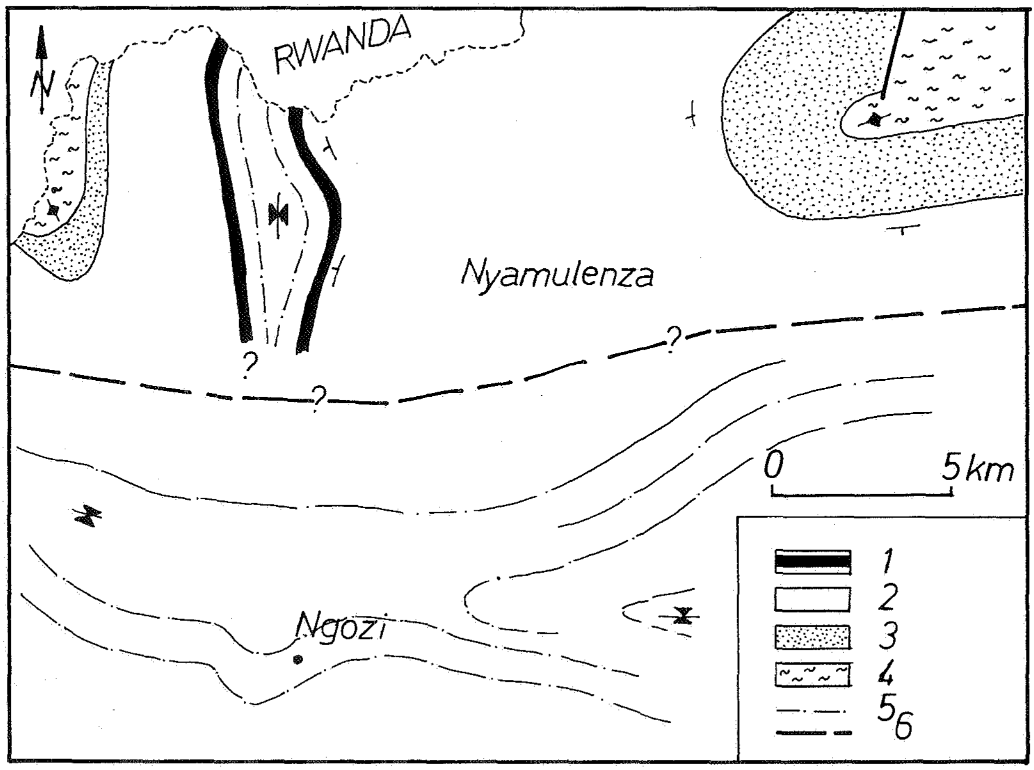


Fig. 7 - Geological sketch map of the Nyamulenza area (after Gérards, 1973):
1 - fine-grained quartz arenites
2 - black and green phyllites including metavolcanic rocks
3 - metaquartzites
4 - micaschists
5 - photogeologically observed structural lines
6 - probable faults.

The ironoxydes which are present throughout the whole Mikiko Formation could be also of detrital origin as we found hematite pebbles in the basal conglomerate and small rock particles impregnated with ironoxydes in the lithic greywackes; the magnetite octahedrons are most probably the result of epizonal metamorphic recristallisation of detrital ironoxydes. Finally it is worth noting that magnetite is abundantly occuring at the same stratigraphical level in eastern Kivu (Itombwe area, VILLENEUVE, 1976, 1979) and in Rwanda (Kamiranzovu-Karamba area, FRAUTSCHI, 1976).

II. THE NYAMULENZA-AREA N of NGOZI :

North of the EW-oriented "Burundian" synform of Ngozi, a thin quartzitic sequence intercalated within grey-black phyllitic shales forms the eastern limb of a NS-oriented synform, W of Nyamulenza.

These sedimentary rocks, which are related to the Burundian (*), surmount a complex of green and black phyllites including a metavolcanic member at the base ("Bugarama"-group") (see fig. 7). The quartzitic sequence is composed of different fine-grained well-sorted quartz arenites, which are mostly finely and rhythmically laminated.

From bottom to top the following formations are distinguished; within each formation the following associations of primary sedimentary structures are observed (VF = very frequent - F = frequent - VR = very rare - R = rare) :

Formation A : grey-black phyllitic shales without obvious sedimentary structures.

Formation B : grey-black finely laminated fine-grained, pyrite-bearing quartzites; at the base a thin subgreywackeous facies occurs. Sedimentary structures : graded bedding (F), planar cross-stratification with sharp set boundaries (VF), herringbone cross-stratification (R), interference ripple marks (VR).

Formation C : fine-grained quartzites with thinly and thickly interlayered white micaceous sandy silt and grey black silty mud. Sedimentary structures : "tidal bedding" (VF), lenticular, flaser and wavy bedding (VF), sharpcrested asymmetrical ripple marks, oscillation ripple marks with rounded crests and pointed troughs (F), clay-draped ripples (F), micro-ripples (R), micro-coss-laminae (R), small-scale convoluted bedding at the top of flaser bedded units (R), erosional unconformities (VR), bioturbata structures (VR).

Formation D : grey-black shales (strongly weathered); no sedimentary structured observed.

Because of the discontinuity of the outcrops and because of the presence of quartz-filled brecciated faults, a detailed and small-scale investigation of the quartzitic sequence has not been possible.

Some rough estimations nevertheless of the thickness of some quartzitic formations can be made : up to 20 m for Formation C; up to 15 m for Formation B (?).

Environmental significance of the primary sedimentary structures observed :

- cross-bedding : herringbone cross-stratification is common to tide-dominated environments, whereas planar cross-stratification with sharp upper and lower set boundaries is characteristic of intertidal sand bodies (SWETT, KLEIN & SMIT, 1971; REINECK, 1972, 1975; KLEIN, 1971, 1972, 1977; REINECK & SINGH, 1973);

- ripple marks : the commonest observed ripple forms are asymmetrical current ripples (L = 3,5 cm - H = 1 cm) which are straight or sinuous in plan view. Locally, current or oscillation ripples with rounded crests and pointed troughs were observed; such ripple marks are very common on intertidal flats (SINGH, 1969). Microripples (L = 1 cm - H = 0,4 cm) are also often met on intertidal flat environments. Some foresets of small-scale cross-bedded units or ripples are draped with mud; these structures are

(*) Lower-Burundian, according to GERARDS (1972); petrographically however, especially the basal beds, very similar to the subgreywackeous facies of the Mikiko Formation (containing fragments of black phyllites with strain-slip cleavage, probably derived from the underlying "Bugarama Group").

common to both modern tidal settings and ancient epeiric and mioclinal shelf arenites (KLEIN, 1977). Interference ripple marks ("rhomboid ripples") are indicators of very shallow water (SINGH, 1969). Ripple lamination in phase (superimposed ripple laminae without drift) is formed in shallow water areas such as deltas, flood plains or intertidal flats (SINGH, 1969; REINECK & SINGH, 1973).
Micro-cross-laminae are most probably the result of deposition from migrating small current ripples.

- Thinly interlayered bedding + lenticular and flaser bedding : the commonest bedding types in mixed-flat environments are flaser and lenticular bedding (REINECK & WUNDERLICH, 1968) in all variations (simple, bifurcated, wavy and bifurcated wavy flaser bedding; lenticular bedding with connected or isolated lenses) with thinly and thickly interlayered sand-mud beds ("rhythmic sand/mud bedding" or "alternating bedding" or "tidal bedding") (REINECK, 1967, 1972, 1975; REINECK & SINGH, 1973). According to REINECK & WUNDERLICH (1968) sand layers are deposited during

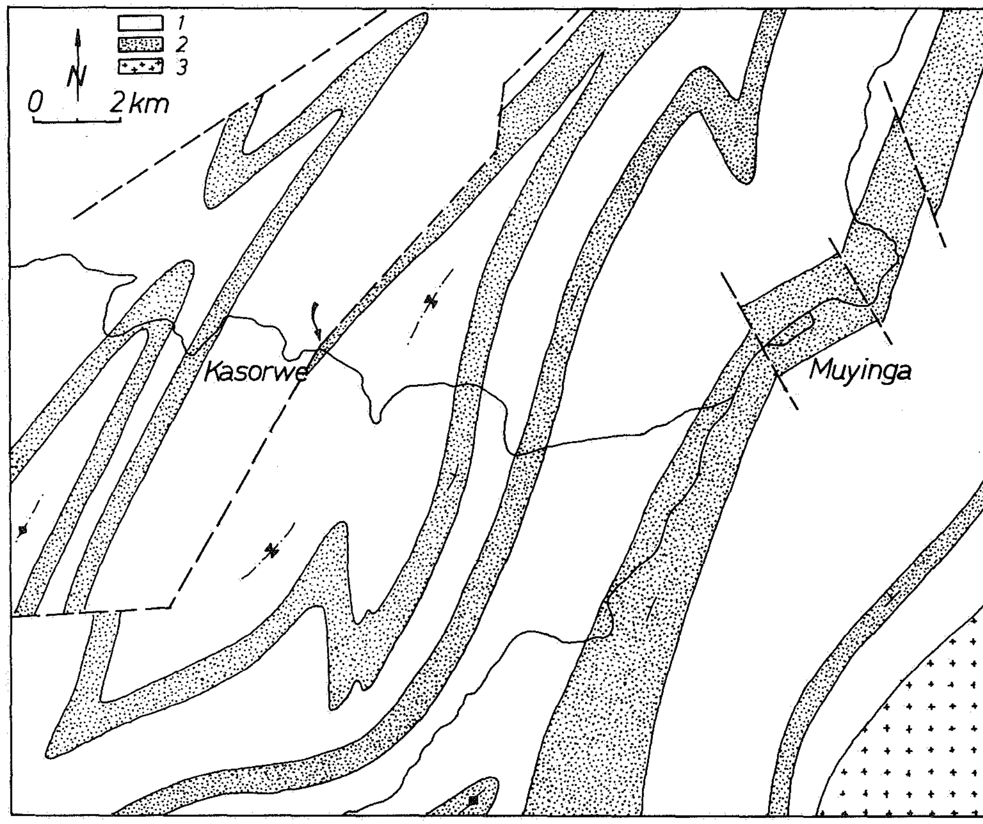
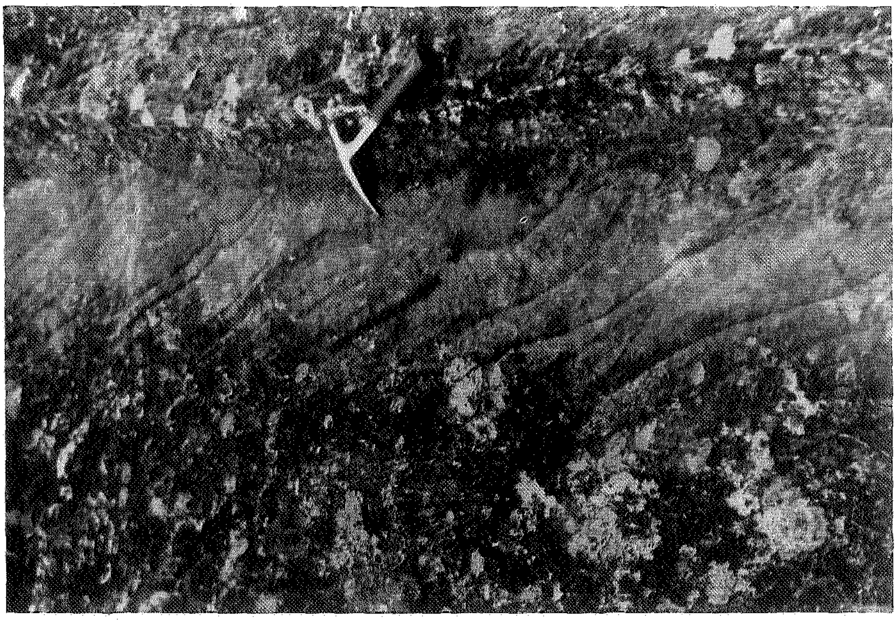
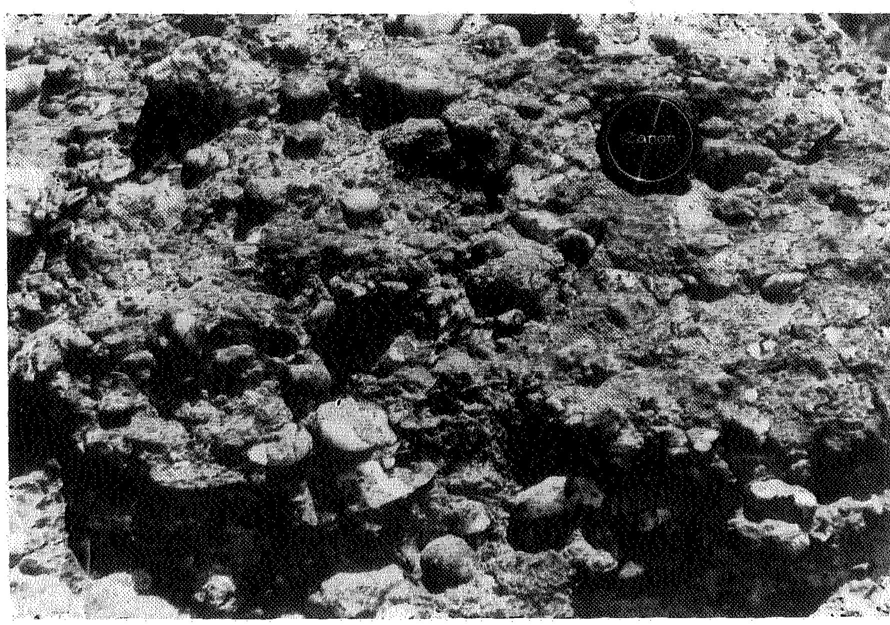


Fig. 8 - Geological sketch map of the Kasorwe-area (after Archives of the Dept. Geol. Mines, Bujumbura, Burundi)
1 - shales and/or phyllites with minor quartzitic intercalations
2 - quartzites
3 - granitoïds

PLANCHE I

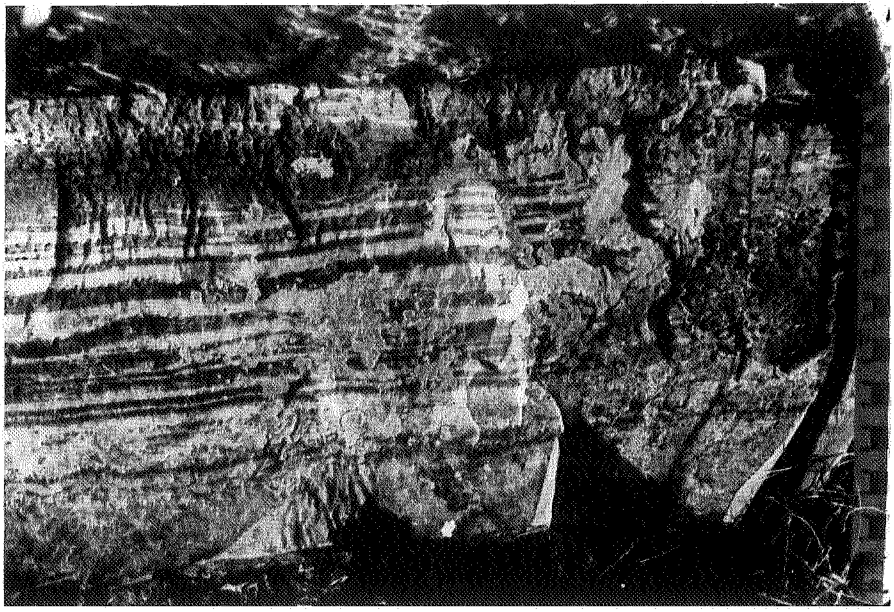


1 : cross-stratification unit with changing dip of the foresets - alluvial sandstones of Mikiko Formation.



2 : fanglomerate - base of Mikiko Formation.

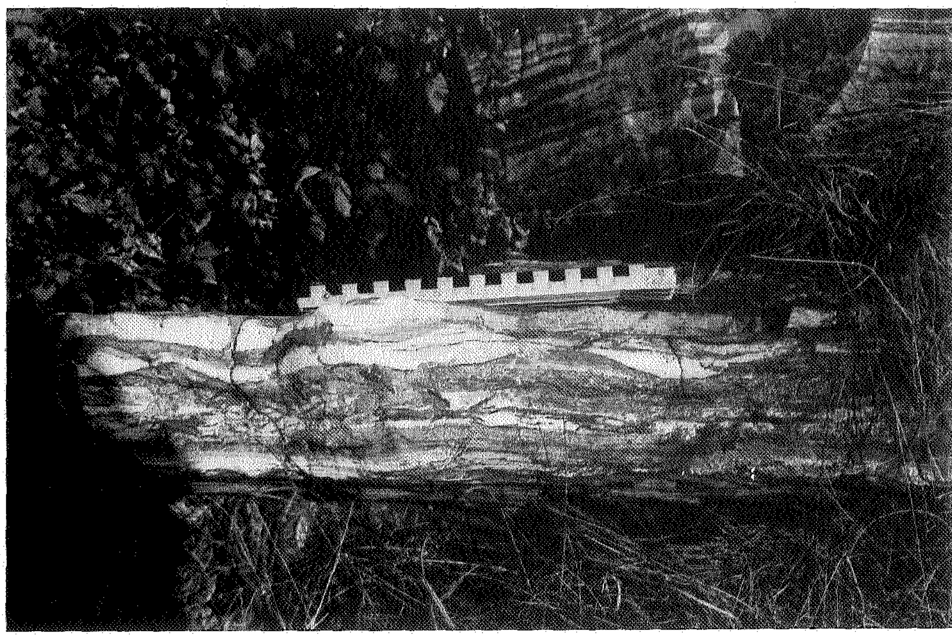
PLANCHE II



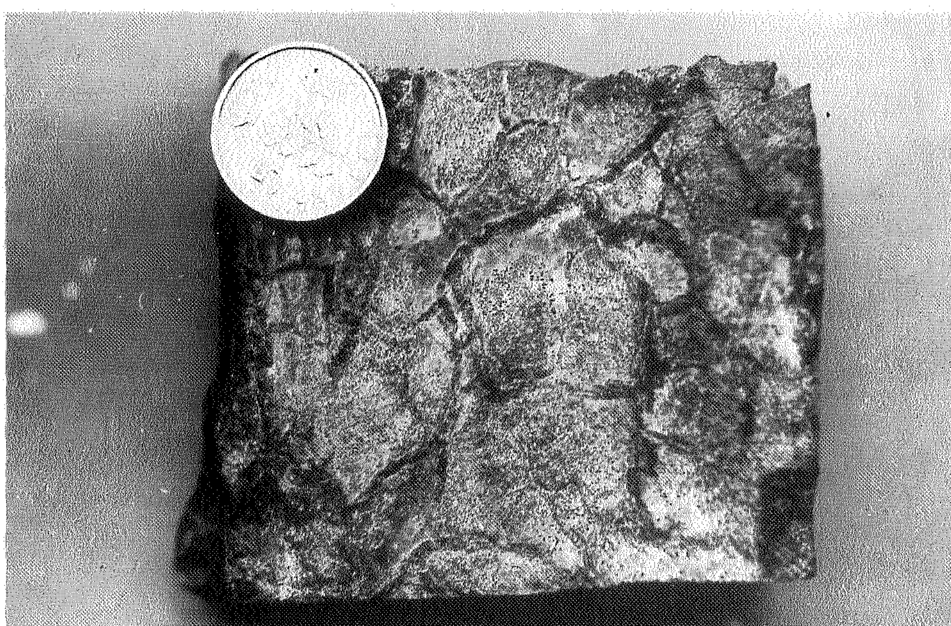
3 : «tidal bedding» : thinly and thickly interlayered muddy silt / silty mud - mixed flat environment - Nyamulenza.

4 : mottled structure and «Monocraterion sp.» trace fossil - mixed flat - Nyamulenza.

PLANCHE III

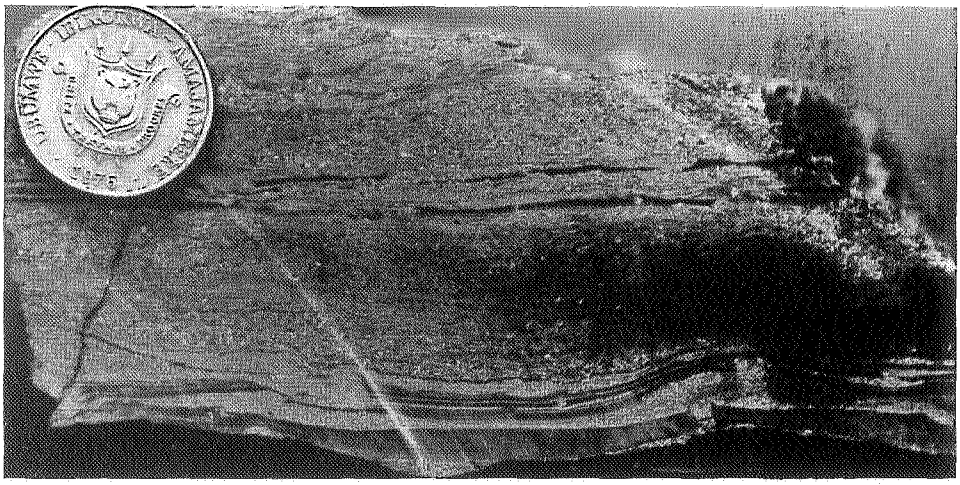


5 : lenticular bedding - mixed flat - Nyamulenza.

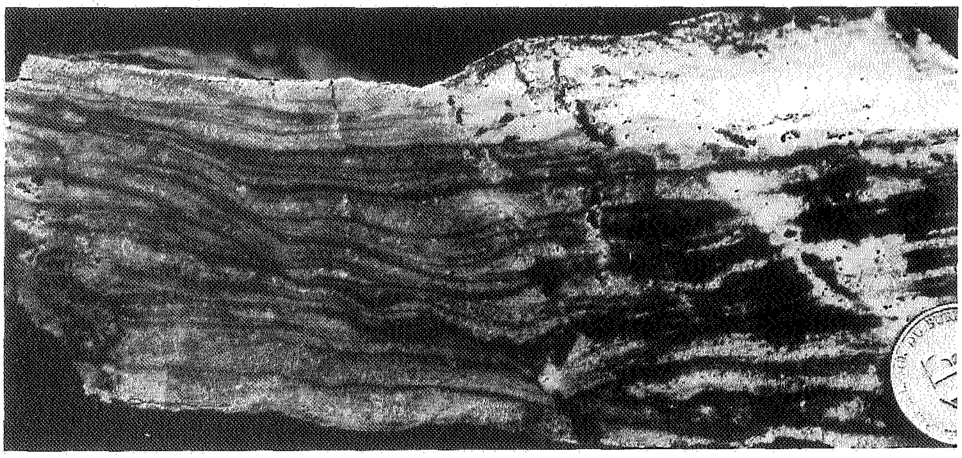


6 : dessication cracks - upper member - Kasorwe section.

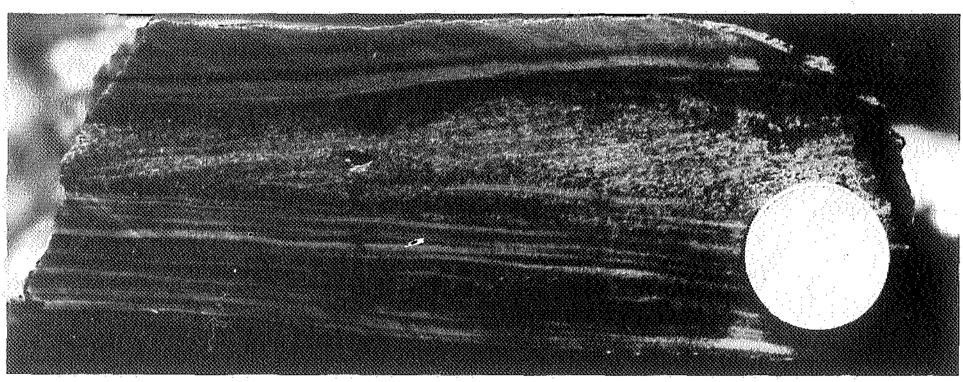
PLANCHE IV



7 : polished slab - dessication cracks - upper member - Kasorwe section.



8 : ripple lamination and incipient ripple drift - coastal sand member - Kasorwe section.



9 : lenticular sand in evenly laminated thinly interlayered muddy silt / silty sand - coastal sand-shelf mud transitional zone - Kasorwe.

periods of flood or ebb current activity; the mud is deposited during stand-still phase of high water and low water tides. These sedimentary structures are very frequent within the studied quartzitic Formation C; all the transitions from flaser bedding to lenticular bedding were observed, strongly ressembling structures from box-core samples from the North sea tidal flats, as illustrated by REINECK (1967, 1972, 1975) and REINECK & SINGH (1973).
- Parallel bedding : evenly laminated sand (or silt) is generally abundantly distributed on beaches (REINECK & SINGH, 1973). According to REINECK (1963) evenly laminated sand is common in tidal environments.
- Erosional unconformities : very locally one may observe some channel fillings, cutting off parallel and rhythmically laminated fine-grained quartzitic layers. Channels are a common feature in the environment of intertidal flats.
- Bioturbate structures : some of the samples from the "tidal bedded" sequence (Formation C) show mottled structures and some rare vertical burrows or escape structures, identical to the Monocraterion escape structures, illustrated by KLEIN (1975).

From the sedimentary structures listed above we may conclude that there is persistent evidence for a tidal origin of the quartzitic sequences studied. Moreover, according to KLEIN (1971, 1972) Formation B to D may represent a regressive intertidalite sequence.
Indeed, we recognize successively a low tidal flat environment (Formation B), a mixed flat environment (Formation C) and must probably a high tidal or mud flat environment (Formation D).

In the studied quartzitic sequences, different association groups of sedimentary features of the tidal circulation model by KLEIN (1970, 1971, 1972) can be recognized (each of them supposing a typical depositional process) :

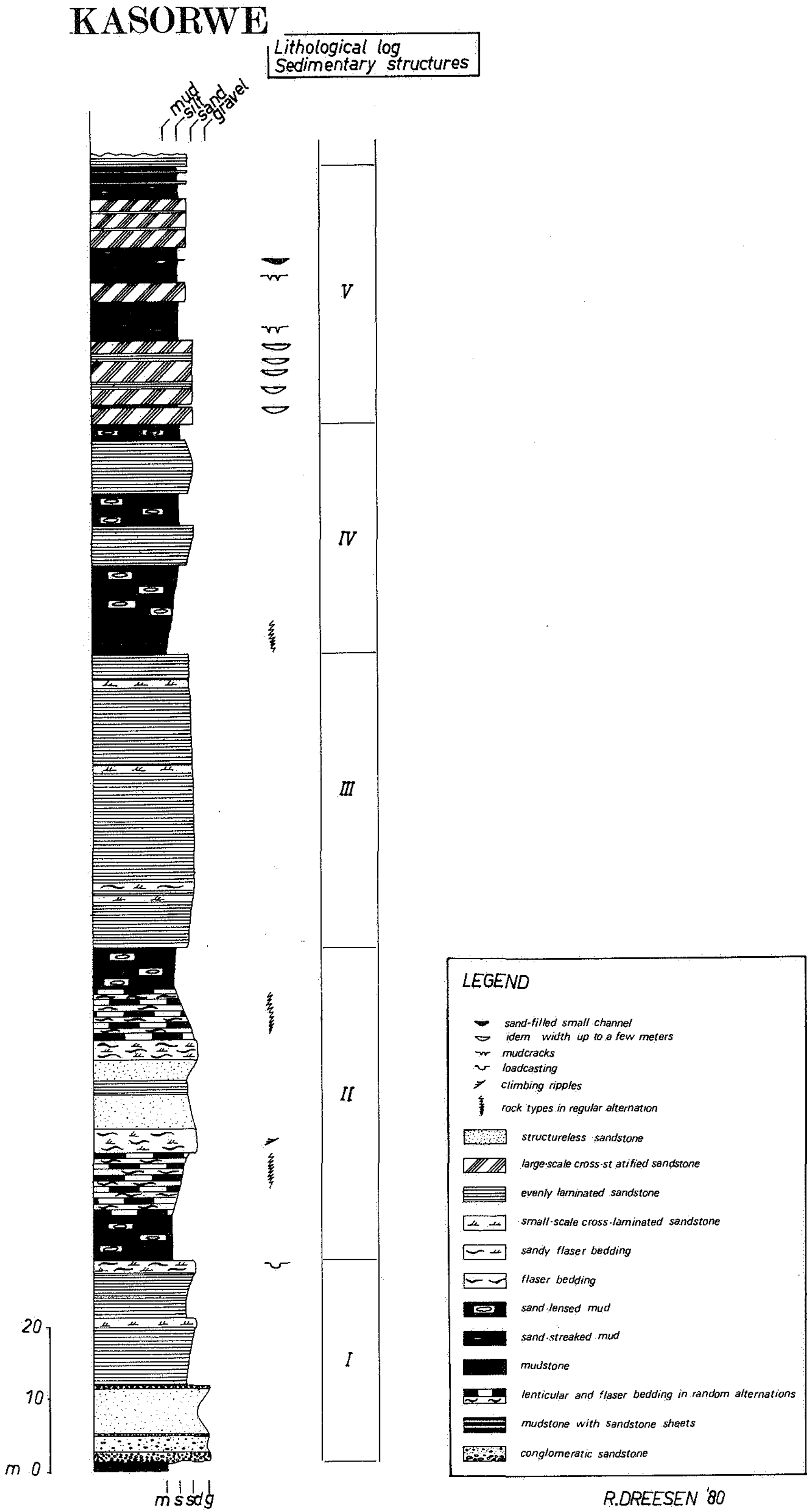
- Group 1, characterized by cross-strata and herringbone cross-stratification with sharp set boundaries; this assumes reversing tidal current bedload transport and tidal current phases of nearly equal flow velocity.
- Group 3, characterized by interference ripples, assumes late-stage emergence run-off, producing changes in flow direction at shallower depths during ebb tide, prior to exposure.
- Group 4, characterized by flaser and lenticular bedding, tidal bedding and clay drapes on ripples, supposes an alternation of tidal current bedload sediment transport with mud suspension deposition during slack water periods, either at high or low tide.
- Group 6 (?) characterized by "escape" burrows supposes a rapid escape by organisms from environment in response to sudden influxes of sediment.

III. THE KASORWE-area W of MUYINGA :

The Muyinga-area (NE-BURUNDI) is the type-area of the Burundian exhibiting a synanticlinorial regular succession of NE-SW elongated quartzitic ridges and phyllitic of shaly depressions, disturbed by longitudinal and transversal faults (see fig. 8).

At Kasorwe, along the main road Ngozi-Muyinga, a well-exposed section of a quartzite-shales alternating sequence has been studied in some greater detail. According to WALEFFE (1965) this quartzitic sequence belongs to the Kahororo Quartzites, an Upper-Burundian formation.

Different lithological units or members are recorded from bottom to top (see vertical log on fig. 9) :


KASORWE
Lithological log
Sedimentary structures
mud
silt
sand
gravel
V
IV
III
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I
20
10
m 0
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LEGEND
sand-filled small channel
idem width up to a few meters
mudcracks
loadcasting
climbing ripples
rock types in regular alternation
structureless sandstone
large-scale cross-st atified sandstone
evenly laminated sandstone
small-scale cross-laminated sandstone
sandy flaser bedding
flaser bedding
sand-lensed mud
sand-streaked mud
mudstone
lenticular and flaser bedding in random alternations
mudstone with sandstone sheets
conglomeratic sandstone
R.DREESEN '80

- Member I : consists of a general fining-upward sequence, composed of several coarsening upward quartzitic sandstones.
  At the very base an upward gradation from a conglomerate to a pebbly sandstone can be seen, with a thin gravelous layer at its top.
  The conglomerate is composed of well-rounded and good-sorted white quartz pebbles embedded in a coarse-grained sandy matrix. In the pebbly sandstone small quartz pebbles occur scattered in coarse sandstone (average size of pebbles in conglomerate : 2 cm; in pebbly sandstone : 0,5 to 1 cm).
  The following homogenous sandstone unit, displaying a reverse graded bedding, is surmounted by finely laminated parallel bedded medium- to coarse-grained sandstone with some rare small-scale cross-stratifications. At the top of this member some mud-draped wave ripples appear in a wavy or flaser bedded sand. In the same facies some questionale load casts occur.

- Member II : is a symmetric sequence of mixed rock types in regular alternation. The transition from this unit to the underlying one is rather abrupt.
  The unit starts with silt- and sand-lensed mudstones that grade into a lenticular-bedded mudstone (grainsize of arenaceous lenses is gradually increasing from bottom to top), followed by a flaser-bedded coarse-grained sandstone and finally by a paralled-laminated medium-grained sandstone.
  The upper half of the sequence is a reverse repetition of the first half.

- Member III : is composed of a thick sequence of parallel-laminated medium-grained white quartzitic sandstone with some small-scale cross-stratification and mud-draped (?) wave-ripples.

- Member IV : is made of an alternation of essentially sand-streaked blackish-grey silty mud and parallel-laminated whitish sandstone grouped into sequences. At the base of the first shaly sequence a regular intercalation of thin evenly laminated sandstones can be observed.

- Member V : is composed of medium- to coarse-grained sandstone sequences with mega-ripples alternating with greyish sand-streaked muddy siltstones. The mega-ripples show strongly tangential and rather gently inclined foreset laminae whose individual units are up to 1 m. Frequent mud cracks are covering the muddy siltstones and some small sand-filled channels may occur.
  The top of the section finally consists of thin sandy intercalations in a greyish silty mudstone.

ENVIRONMENTAL INTERPRETATION OF THE KASORWE SECTION.

According to the examples of beach-shelf profiles from modern environments (REINECK, 1971, 1972 - HOWARD & REINECK, 1972 - SELLEY, 1970 in : REINECK & SINGH, 1973), the lithological units observed (members I to V) within the Kasorwe section, are considered as clastic sediments deposited in different subenvironments of a nearshore coastal area of a tidal sea :

Member I, consisting of well-sorted, regular-bedded, evenly-laminated coarse sands represents a transgressive coastal sand deposit, grading from a swash zone (gravelous beds), through an upper-shore face (dominantly evenly laminated sand) to a lower-shore face (small ripple bedding, mud flasers).

Member II consists very probably of upper offshore sediments, deposited in the deeper coastal sand-shelf mud transition zone, characterized by interbedded sand and mud displaying flaser and lenticular bedding types and paralled lamination.

This member is composed of dark-coloured clayey silt layers alternating with lighter-coloured silty fine sand layers (thinly mm to cm-sized interlayering) and lenticular sandstone beds (5 to 10 cm units); these lenticular sand beds are interpreted as storm layers, becoming thicker and coarser toward land, ultimately grading into coastal sand (middle of the unit).
The source of sand of these sand layers is assigned to coastal sand eroded in the nearshore environment during heavy storms and storm tides and transported to the shelf region by retreading waves and ebb current (REINECK & SINGH, 1973).
A regressive-transgressive rhythm may be deduced from the symmetrical outline of this member.

Member III is also interpreted as a beach sand, characterized by medium-grained evenly laminated sand and rare small-scale cross-stratification.

Member IV is probably the result of alternating coastal sand and shelf-mud environments.

Member V finally, may represent a rather restricted marine environment : it is characterized by a mainly silty mud sedimentation and dessication cracks : these features suppose low -energetical shallow-water conditions and a frequent subaerial exposure.
The presence further of large-scale cross-bedding, attributed to migrating mega current-ripples in tidal channels, supposes a connection with a tidal sea through a tidal inlet system.

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