

A FOSSIL EVERGLADES-TYPE MARL PRAIRIE AND ITS PALEOENVIRONMENTAL SIGNIFICANCE

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ABSTRACT

Located at the interface between land and sea, marl prairies are sensitive to changes in water balance and useful recorders of climate and sea-level changes. Palustrine carbonate in marl prairies precipitates in temporary, barely flooded grasslands within microbial mats. Despite the special mode of carbonate production, descriptions of the sedimentary facies are exceptional and cursory because marl prairies are so far reported only from the recent of the Everglades (Florida, USA), where they produce an unspectacular calcite mud. We present a Pleistocene Everglades-type marl prairie from coastal Tanzania as the first fossil example. The unique preservation and high productivity (two times higher than in the Everglades) of the periphyton community in this marl prairie is due to increased calcification of coccoid and filamentous cyanobacteria. The excellent preservation allows us to characterize a marl prairie facies in great detail for the first time. Facies analyses of the sediments reveal a transition from tidal to terrestrial settings that started at ca. 44 ¹⁴C ka in response to eustatic sea-level fall and coastal tectonic uplift. The resultant drop of the groundwater table triggered the development of the marl prairie. The decline of the marl prairie was initiated at ca. 33 ¹⁴C ka due to the onset of the Last Glacial Aridity Maximum in equatorial East Africa.

INTRODUCTION

Marl prairies are seasonal wetlands only described from the present-day Floridian Everglades (USA), where they occupy higher-elevation sites and border the deeper sloughs (Platt and Wright, 1992; Davies et al., 2005). Marl-prairie vegetation is characterized by grasses, scattered trees, and patches of forests locally rising above ordinary flooding (tree islands) (Browder et al., 1994; Lodge, 2004). The sediment is light brown to grey, unstructured calcite mud (median crystal size 8 μ m), frequently containing plant roots and freshwater snails (Scholl, 1964; Merz, 1992). It forms a distinct horizon in the Everglades that is traceable beneath the sequence of deposits formed by the rise in sea level over the past 4 ka (Scholl, 1963; Wanless, 1974).

Drastic seasonal hydrological changes are a prerequisite for the development of marl prairies. During intervals of pronounced flooding and desiccation, periphyton mats grow in shallow (≤ 50 cm, mean 10 cm), light-suffused water (Olmsted et al., 1980; Merz, 1992). These mats contain a complex community of algal, bacterial, and cyanobacterial species (dominated by *Scytonema* and *Schizothrix*) and can calcify in an alkaline environment low in nutrients (Merz and Zankl, 1993; Browder et al., 1994; Davis et al., 2005). Longer hydroperiods cause marsh development with build-up of organic soils (Swift, 1984), while shorter hydroperiods cause development of dry prairie and woodland (Hilsenbeck et al., 1979). Accordingly, in large parts of the Everglades, the marl prairie expanded during the last century in response to anthropogenic drainage of sawgrass marshes (Davies et al., 2005; Bernhardt and Willard, 2006). Freshwater carbonates showing evidence of subaqueous deposition and subaerial exposure are termed palustrine

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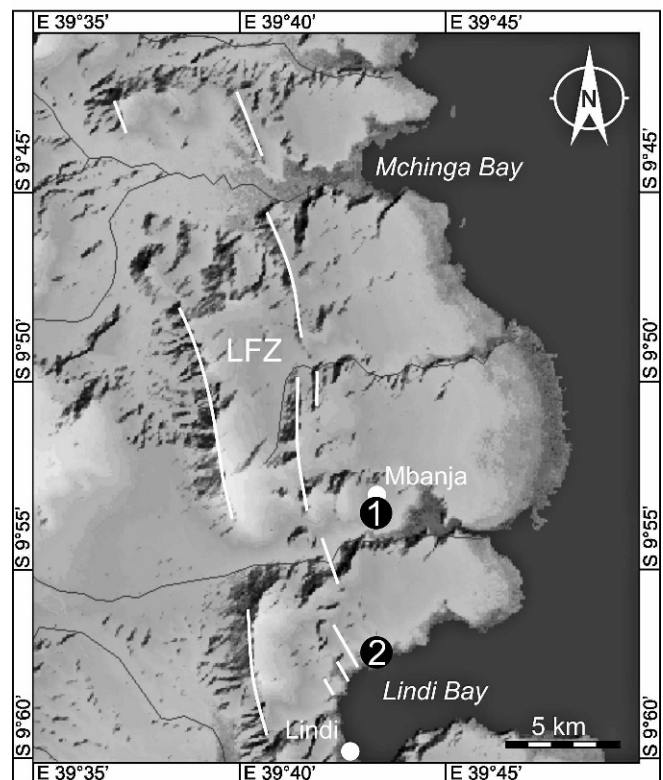


FIGURE 1—Location of study site (above) and digital elevation model (below) showing the flat topography of the coastal terrace in front of the Lindi Fracture Zone (LFZ). The studied outcrop (1) is located between Lindi Bay and Mchinga Bay (southern Tanzania) at 09°53.34'S, 39°43.37'E. Palustrine limestone boulders also occur in the coastal conglomerate at Ras Tipuli (2).

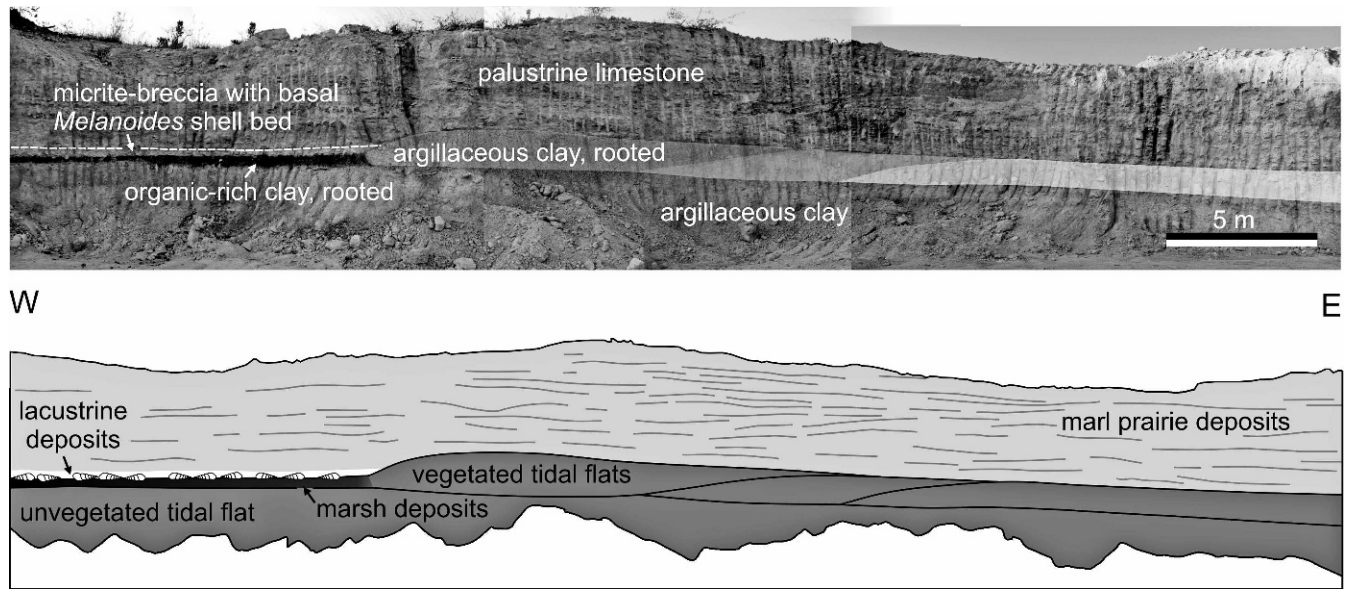


FIGURE 2—Stratal geometries and facies architecture in the Mbanja quarry.

carbonates (Freytet and Plaziat, 1982), and marl prairies have been suggested as a modern analogue for their genesis (Platt and Wright, 1992).

Because of the narrow environmental constraints, marl prairies are exceptional settings for carbonate production and are short lived in geological terms (Platt and Wright, 1992; Wright and Platt, 1995). Therefore, the occurrence and preservation potential of marl-prairie deposits in the geological record is low, resulting in sparse information about the sedimentary facies of marl prairies and a lack of data outside the Everglades. This article focuses on the facies of a late Pleistocene marl prairie from equatorial East Africa (Tanzania) in order to compile criteria for the identification of a marl prairie in the geological record and to introduce marl-prairie deposits as a new and sensitive archive for seasonal as well as long-term changes in the past hydrological balance.

GEOLOGICAL SETTING AND STRATIGRAPHY

The sedimentary succession at the study site formed on a Pleistocene coastal terrace that extends between Lindi Bay and Mchinga Bay (southeastern Tanzania) and is located in front of the NNW-trending Lindi Fracture Zone (LFZ; Fig. 1; Nicholas et al., 2007). The studied outcrop is a quarry 1 km south of the village of Mbanja on the road to Lindi (09°53.34'S, 39°43.37'E) which was temporarily active for road work during the summer of 2007. The outcrop situation in the quarry is exceptional for the Tanzanian coast because the exposed sedimentary succession is laterally continuous for ~300 m and the recently exposed sediments are so far unaffected by vegetation and weathering. The quarry cuts a 10-m-thick palustrine limestone unit that covers a unit of calcareous clay at least 2 m thick, which is deposited on tidal flats. The uppermost tidal flat merges laterally into a deposit of black, organic-rich clay that is interpreted to have formed in a marsh (Fig. 2). Radiocarbon dating of *Assiminea* gastropods indicate Weichselian (=Wisconsinian) ages for the organic-rich clay (43,983 ± 1,907/–1,540 ¹⁴C yr BP) as well as for the top of the palustrine succession (33,112 ± 487/–459 ¹⁴C yr BP).

Palustrine limestone boulders also occur in the coastal conglomerate at Ras Tipuli, 5.5 km to the southeast, pointing to a former extensive distribution of the sediments in front of the LFZ (Fig. 1). Unfortunately, a more detailed and extensive mapping of the palustrine limestone deposit was not possible because of the deep-reaching tropical weathering and dense vegetation at the coast.

PALUSTRINE LIMESTONE FACIES

The palustrine limestone has a high intergranular and moldic porosity (>50% depending on the degree of cementation) and exhibits irregular, wavy bedding ranging in thickness from several millimeters to several centimeters due to variable degrees of cementation. A friable, peloidal facies is dominant and is characterized by fuzzy, undulating bedding (Fig. 3A), which is caused by layers with dense packing of peloids that are clustered in chains or groups, producing a clotted fabric. The peloids have a cloudy, fine-grained nucleus and a coarser-grained rim of euhedral calcite crystals. Their sizes range between 120 and 175 μm. Clumps (*sensu* Chafetz and Folk, 1984) of widely oval to cylindrical rods with rounded ends are present in this facies (Fig. 3B). Thin, well-cemented layers (<5 mm thick) are intercalated in the peloidal facies (Fig. 3C) and composed of adjacent irregular shrubs (*sensu* Love and Chafetz, 1988) consisting of radial palisadic sparite crystals. Tubelike molds of reed stems are further typical features of the peloidal facies and are often encrusted by radial palisadic sparite crystals (Figs. 3C–D) or by clotted micrite (thrombolite) containing various amounts of filament traces (Fig. 4). Centimeter-thick, porous crusts with layer-cake architecture due to an alternation of creeping and erect tubes (diameter of ~15 μm) are also interbedded (Fig. 3E). The small tubes are open and surrounded by tiny calcite needles forming a boxwork fabric (Fig. 3F). Only locally does the boxwork show transformation into bladed calcite spar and the beginning of cementation in the pore space (Fig. 3G). Better-cemented, centimeter-thick crusts are build-ups of closely spaced, intertwined, dark micrite tubes forming coherent mats (Fig. 3H). The relatively long and thick (diameter of 60–90 μm) tubes are surrounded by equidimensional calcite crystals. Other well-cemented layers comprise a high content of coarse phytoclast debris (molds of reeds and leaves of deciduous trees). These layers have high shelter and moldic porosities. Needle-fiber calcite crystals (Fig. 5A) are abundant constituents of the palustrine limestone. They are concentrated in vugs that derived from decayed roots (Fig. 5B) and in rhizocretions (Fig. 5C). The fauna in the palustrine limestone is represented by abundant gastropods, including *Melanoides tuberculata* (Fig. 6A), *Assiminea* cf. *aurifera* (Fig. 6B), *Tropidophora anceps*, *Cyathopoma* sp., *Lissachatina* cf. *fulica* (Fig. 6C), *Homorus* cf. *silvicola*, *Pseudopeas* sp., *Gulella* sp., Urocyclidae indet., *Pseudoglessula* cf. *bovini*, *Gonospirax* sp., *Halo-*

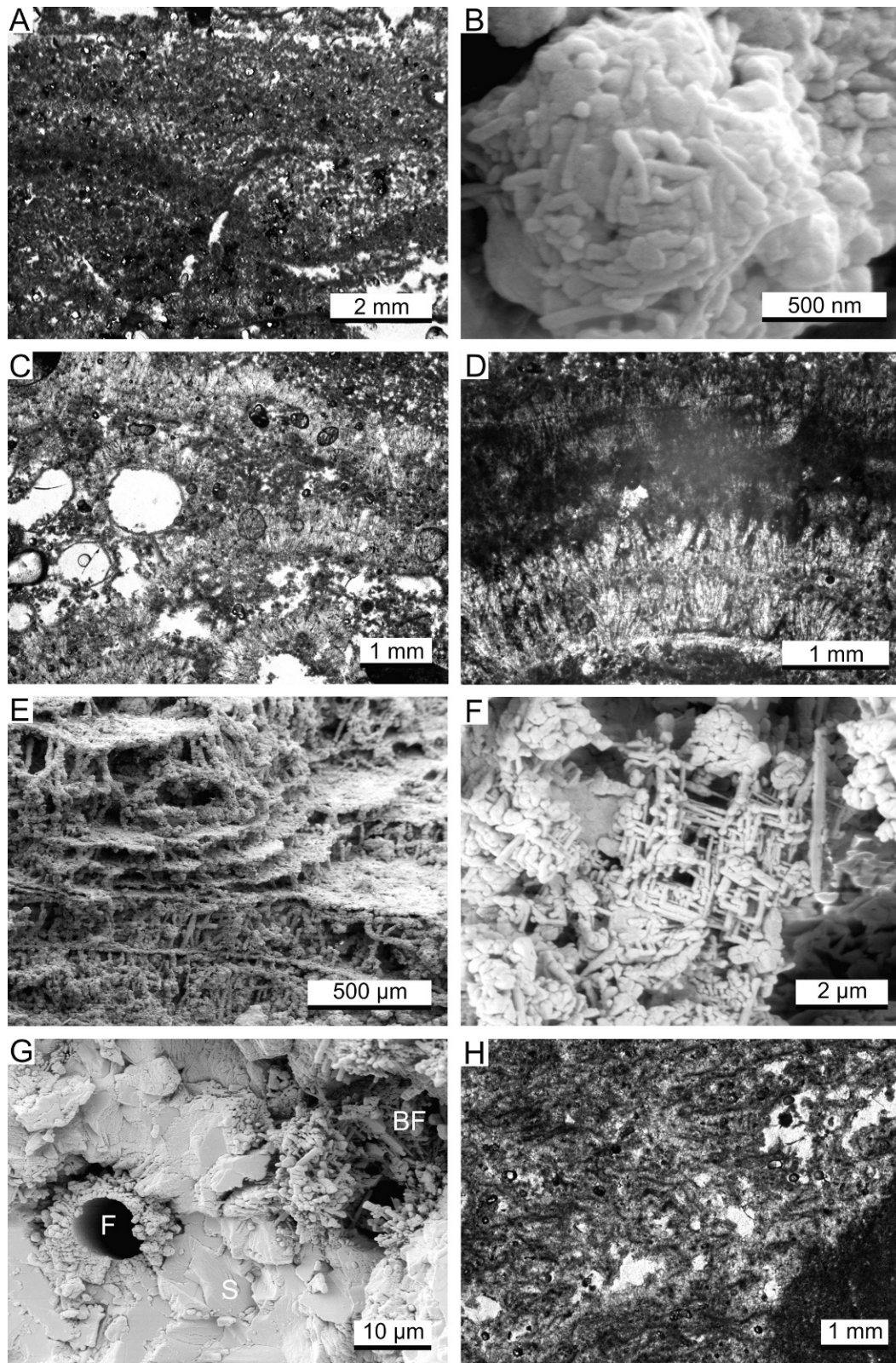


FIGURE 3—Periphyton community. A) Clotted fabric and fuzzy, wavy bedding in peloidal limestone. B) Calcified microbial clump composed of rods that are reminiscent of coccoid cyanobacterial cells (cf. *Aphanothece*). C) Peloidal limestone with intercalated layers made of adjacent fascicles of radial palisadic calcite crystals, which developed through recrystallization of cyanobacterial shrubs. D) High magnification of radial palisadic calcite crystals; the dark internal laminations point to *Schizotrix*. E) Alternation of thin, creeping and erect filaments as described from Scytonemataceae. F) Calcite crystals with boxwork fabric are characteristic of some Scytonemataceae; they occur around the filament tubes in the laminated cyanobacterial mats. G) Recrystallization of a Scytonemataceae mat; F = tubelike mold of a cyanobacterial filament; S = sparite; BF = relics of calcite crystals with boxwork fabric. H) Thin section of a well-cemented cyanobacterial mat composed of intertwined micrite tubes surrounded by equidimensional calcite spar.

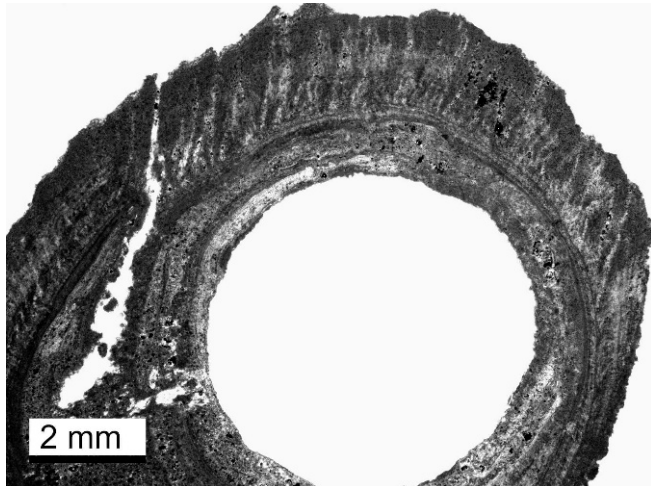


FIGURE 4—Concentric thrombolite crust with traces of cyanobacterial filaments surrounding a rod mold.

limnohelix sp., and *Limax* sp., as well as a monospecific *Psychrodromus* ostracode assemblage.

A lens-shaped deposit (≤ 20 cm thick, ~ 30 m wide) of light gray micrite-breccia (Fig. 5D) is intercalated at the base of the palustrine-limestone succession (Fig. 2). The sediment is intensively rooted and the

empty rootlets are filled with needle-fiber crystals (Fig. 5B). A shell bed composed of *M. tuberculata* occurs at the base of the micrite deposit. Ostracodes are abundant in this facies and represented by *Microdarwinula* sp., *Vestalenula* sp., *Psychrodromus* sp., *Stenocypris* sp., *Ilyocypris* sp., *Kovalevskiella* sp., and Cyprididae indet. Parts of charophytes are also common (Fig. 5D).

CARBONATE PRODUCERS

Wavy bedding produced by clotted fabrics (Fig. 3A), as well as associated microbial clumps (Fig. 3B), indicate a microbial origin of the peloids (Chafetz and Folk, 1984; Chafetz, 1986). The shape and dimension of the rods from the microbial clumps are reminiscent of coccoid cyanobacteria cf. *Aphanothece* (e.g., Freydet and Plet, 1996, plate 57, fig. 3). Radial palisadic calcite crystals, which form layers on bedding surfaces in the peloidal sediment and around plant remains (Figs. 3C, D), developed through recrystallization of filamentous cyanobacterial shrubs (Love and Chafetz, 1988). The dark internal laminations in some radial palisadic calcite crystals (Fig. 3D) point to *Schizotrix* (Freydet and Verrecchia, 1998, 1999). Filamentous cyanobacteria are also documented by the layer-cake porous crusts (Fig. 3E). The alternating layers of creeping and erect filaments, which comprise box-work calcite crystals, indicate the presence of Scytonemataceae (e.g., Merz, 1992, pl. 20; Freydet and Verrecchia, 1998). Filament traces in thrombolite crusts (Fig. 4), as well as the thicker intertwined

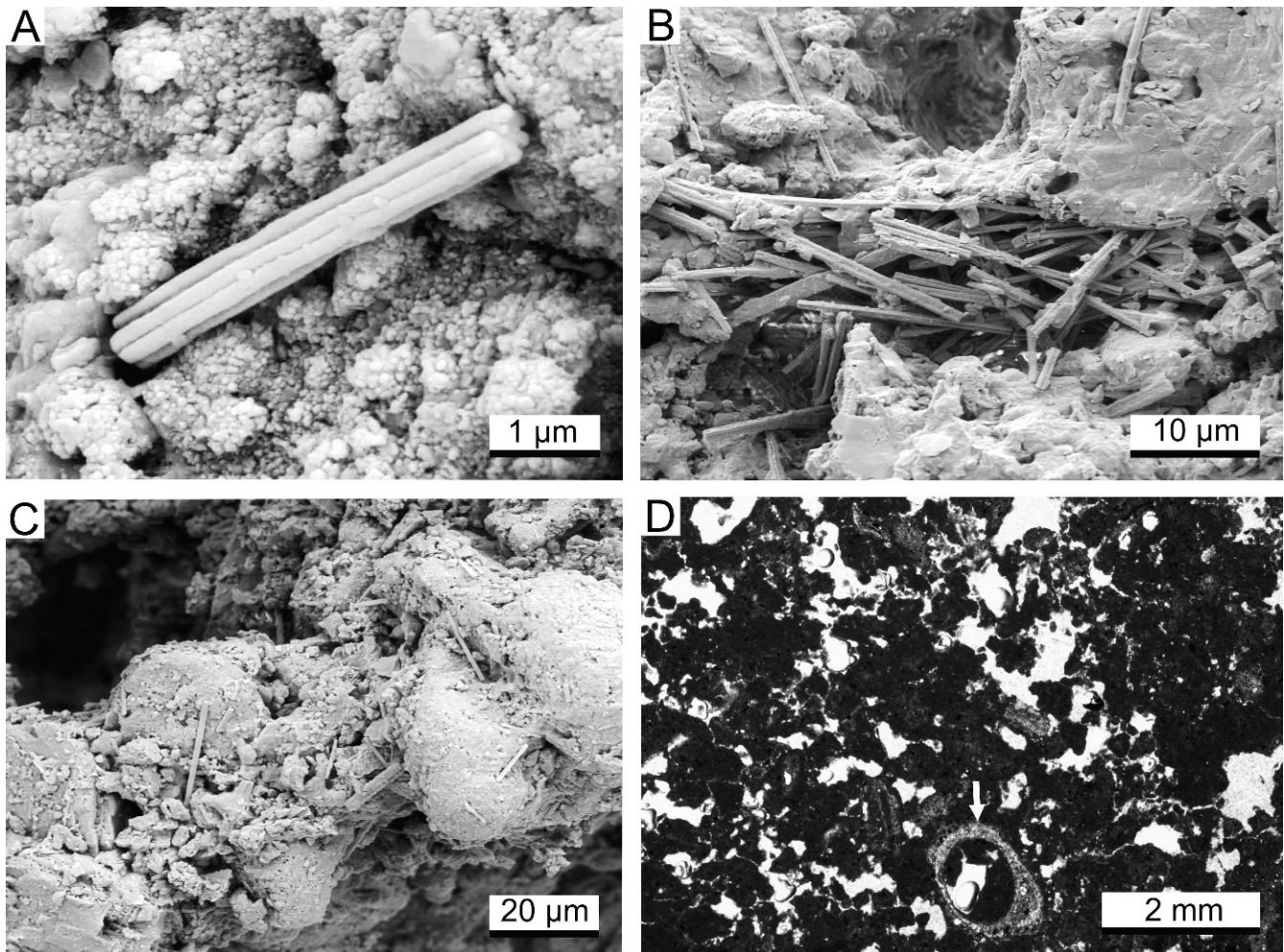


FIGURE 5—Evidence of desiccation. A) Isolated needle-fiber calcite crystal; these biomineralizations were precipitated in the vadose zone by fungal mycelial strands. B) Concentration of needle-fiber calcite crystals in a rootlet; micrite at the base of the palustrine succession. C) Needle-fiber calcite crystal accumulation in a rhizcretion; peloidal limestone. D) Micrite-breccia showing oblique view of a charophyte node (arrow).

filaments in well-cemented mats (Fig. 3H), also imply the activity of filamentous cyanobacteria (Ferris et al., 1997) of unknown taxonomic affiliation.

DEPOSITIONAL ENVIRONMENT

The low relief and horizontal bedding, as well as the consistent facies of the palustrine limestone body (Fig. 2), suggest a paludal origin (Pedley, 1990). The presence of reedlike vegetation is indicated by the dominance of tubelike plant molds in the palustrine limestone (Fig. 7A). The high abundance of leaves within the palustrine limestone, however, also indicates the presence of woody vegetation (Fig. 7B). Since competition with taller plants usually determines the extent of reedlike and periphyton growth (Gleason and Spackman, 1974), trees must have grown scattered within the reeds or locally concentrated on tree islands (Fig. 7B). In the Everglades marl prairies, calcifying periphyton occurs to a maximum depth of 0.5 m in transparent water, but it is less abundant when shaded by macrophytes and calcification will only occur at shallower depths of ~0.1 m (Gleason and Spackman, 1974; Olmsted et al., 1980).

The gastropod fauna in the palustrine limestone is characterized by the dense occurrence of the freshwater snail *Melanoides tuberculata* (Fig. 6A). This species prefers shallow areas (≤ 1.2 m) in lakes and slowly running rivulets (Neck, 1985). *Psychodromus* ostracodes are abundant freshwater elements and characteristic for boggy springs (Preece and Robinson, 1984). In contrast, the light gray micrite-breccia that is interbedded at the base of the palustrine limestone (Figs. 2, 5D) contains a more diverse freshwater ostracode fauna; *Ilyocypris* and *Limnocythere* species indicate open, quiet waters (Preece and Robinson, 1984; Preece et al., 1986). Accordingly, the micrite is interpreted as lacustrine sediment that formed in a lentic pool with aquatic vegetation (e.g., charophytes, Fig. 5D) where photosynthesis and evaporation took place. The lack of calcareous periphyton in this facies is assumed to reflect a greater water depth compared to the depositional environment of the periphyton facies.

The majority of gastropod taxa in the palustrine limestone, however, are terrestrial (e.g., Fig. 6C) and indicate vegetated, moist areas with leaf litter. Terrestrial environments are indicated by rodlike calcite needles as well (Figs. 5A–C). These biomineralizations have been reported from vadose environments in paleosols and travertine deposits (above groundwater level) and are formed within fungal hyphae or root-encrusting fungal mycelia (Verrecchia and Verrecchia, 1994; Janssen et al., 1999; Bajnóczy and Kovács-Kis, 2006). Rodlike, needle-fiber calcite crystals are, therefore, concentrated in vugs, which originated from decayed rootlets (Fig. 5B) and in rhizocretions (Fig. 5C). Waterlogged soils have been shown to impede colonization of mycorrhizal species (Smith and Read, 1997) and, consequently, needle-fiber calcite crystals are lacking in the underlying organic-rich clay.

WATER BALANCE

Seasonal Water Balance

The apparently conflicting co-occurrence of terrestrial and freshwater biota in the palustrine limestone can be explained by temporary water cover (Freytet and Plaziat, 1982). Present-day rainfall in mainland Tanzania is highly seasonal with peaks in March–May and October–December, interrupted by an extended dry season in June–September (Zorita and Tilya, 2002). Quaternary climate variations in equatorial East Africa show a simple relation: cool climates are associated with dry episodes and warm climates with wet phases (Pinot et al., 1999). The last interglacial climate is considered to represent a close analogue to the present climatic conditions (Trauth et al., 2001) and, subsequently, global ice-volume build-up during the Weichselian was

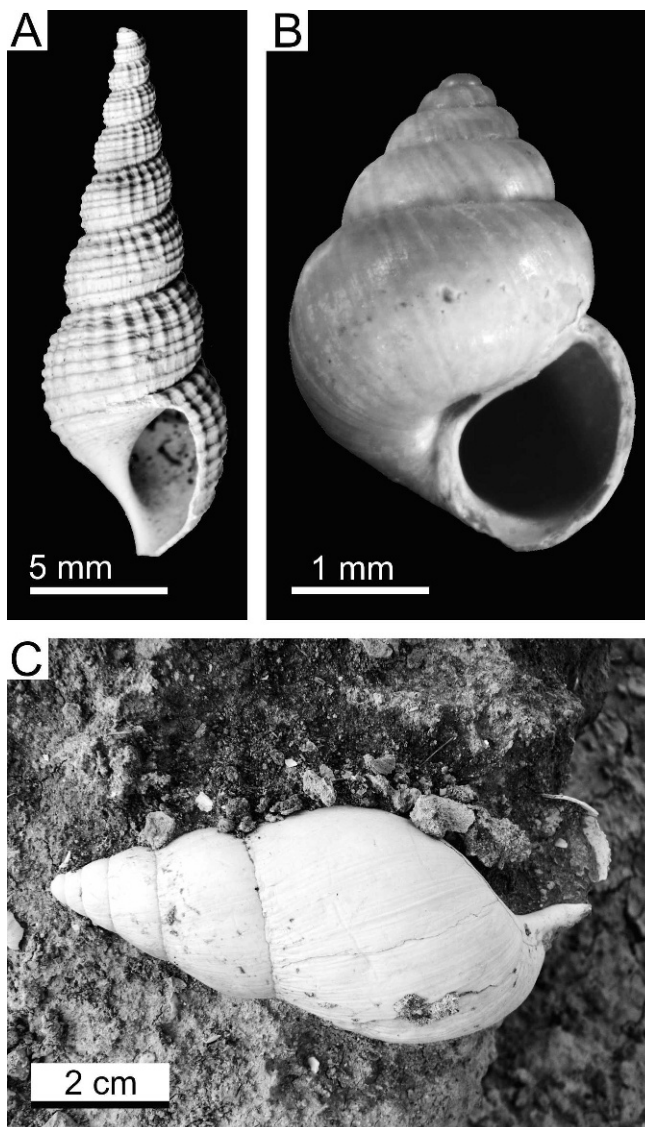


FIGURE 6—Marl-prairie gastropods. A) Freshwater gastropod *Melanoides tuberculata*, a common inhabitant of the inundated marl prairie. B) The semi-aquatic marsh snail *Assiminea* cf. *aurifera* tolerates higher salinities and is the dominant gastropod species in the palustrine limestone as well as in the underlying organic-rich clay. C) Large terrestrial gastropod (*Lissachatina* cf. *fulica*); the terrestrial biota invaded the desiccated marl prairie during the dry seasons.

accompanied by decreasing precipitation in equatorial East Africa (Gasse, 2000). For the last glaciation maximum, most hydrological records in tropical Africa indicate generally dry conditions with reduced summer rainfall in both hemispheres, associated with lower tropical land- and sea-surface temperatures (Gasse, 2000). Evaporation and desiccation during a prolonged drought period favor carbonate precipitation, suppress growth of higher plants, and oxidize any organic matter during the hydroperiod (Gleason et al., 1984). Mycorrhizae often strengthen the drought resistance of their host plants (Allen and Allen, 1986; Nelsen, 1987; Ruiz-Lozano et al., 1995). Hence, the occurrence of needle-fiber calcite crystals in the palustrine limestone (Figs. 5A–C) may indicate adaptation of the plants to enduring periods of desiccation. Accordingly, the discrete leaf layers (Fig. 7B) may have formed at the beginning of dry seasons. At that time, deeper pools may have acted as retreats for aquatic biota (Jeffries, 1994), although from time to time even these may have dried up. This scenario is indicated by brecciation of the lacustrine calcite mud (Fig. 5D), suggesting that alternating shrinkage and expansion

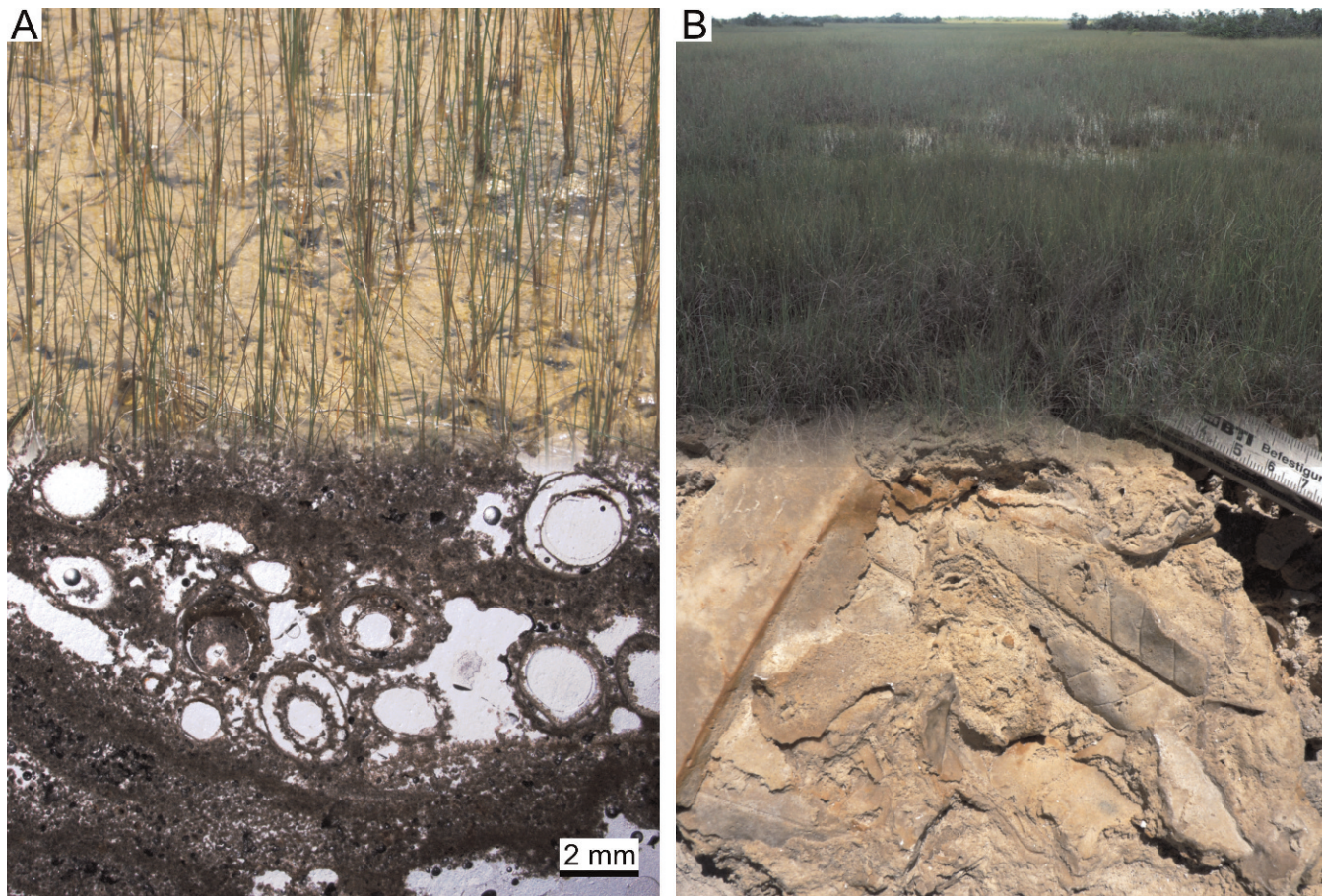


FIGURE 7—Fossil (below) and recent (above) marl-prairie vegetation. A) Periphyton-reed association; periphyton mats between sawgrass in inundated marl prairie south of Shark Valley Visitor Center, Florida Everglades (above) and stems of reed plants embedded in peloidal limestone, Mbanja, Tanzania (below). B) Woody vegetation; spotty tree clusters on higher elevated sites (tree islands) in the marl prairie south of Shark Valley Visitor Center (above) and phytoclast limestone with impressions of leaves of deciduous trees at Mbanja (below; scale in cm).

processes took place in the soil (Freytet and Plaziat, 1982; Platt and Wright, 1992; Bain and Foos, 1993), and by the occurrence of needle-fiber calcite crystals in abundant rootlets (Fig. 5B; Smith and Read, 1997). Accordingly, we interpret the *Melanoides* shell bed at the base of the micrite lens to have formed while gastropods sought refuge in the deepest part of a shallow pool immediately before its desiccation.

Long-Term Water Balance

A shortening of the hydroperiod can be inferred to be the main reason for the appearance of calcareous periphyton in settings where peat substrate suggests no previous calcite deposition (Gleason and Spackman, 1974). At Mbanja, this shortening of the hydroperiod was an effect of the exposure above high-tide level at ca. 44 ^{14}C ka, which is reflected in the transition from organic-rich marsh deposits to palustrine limestone (Fig. 2). Today this transition occurs at 21 m above present-day sea level. Assuming that the ice-volume-equivalent sea level at 43,983 \pm 1,907/–1,540 ^{14}C yr BP was 60–90 m below present-day sea level (Fig. 8), the emergence of the Lindi coast at ca. 44 ^{14}C ka and subsequent elevation to 21 m above present-day sea level was not only linked to the falling eustatic sea level prior to the Last Glacial Maximum (Fig. 8), but also to a period of tectonic activity along the southern Tanzanian coast (Nicholas et al., 2007), which caused uplift at the Lindi Fracture Zone.

The decline of the marl prairie at ca. 33 ^{14}C ka corresponds with the beginning of the Last Glacial Aridity Maximum (LGAM) in equatorial East Africa, which lasted from 32 to 14 ka (Fig. 8; McGlue et al., 2007).

Multi-proxy records from Crater Lake Triterivakely in the Madagascar highlands show a positive precipitation-minus-evaporation (P–E) balance in East Africa from ca. 38 to 32 ka, followed by a stepwise desiccation trend (Gasse and Van Campo, 1998; Williamson et al., 1998). As a consequence of this megadrought, the rainforests in equatorial Africa were greatly reduced (Anhuf et al., 2006), the rift lakes in East Africa (e.g., Lake Tanganyika) shrank drastically (Farrera et al., 1999; McGlue et al., 2007), and even Lake Victoria, the largest lake in Africa, was desiccated from ca. 20 to 15 ka (Talbot and Livingston, 1989; Johnson et al., 1996).

SEDIMENTATION RATES AND FOSSILIZATION POTENTIAL OF MARL-PRAIRIE PERIPHYTON

Despite eustatic sea-level fall and continued uplift (21 m above present-day sea level), a 10-m-thick palustrine limestone deposit (Fig. 9A) formed in the marl prairie between ca. 44 and 33 ^{14}C ka (Fig. 8). This indicates sedimentation rates of \sim 1 m/l ka, which is much higher than in the Everglades marl prairies. Scholl (1964) reported an average thickness of 1.2 ft. (0.37 m) for marl-prairie deposits at Whitewater Bay in southwestern Florida. This marl prairie was relatively short lived (from 4 to 3 ka) before it was terminated by mangrove sedimentation in response to Holocene sea-level rise (Scholl, 1963, 1964; Scholl et al., 1969). From ^{14}C data, Scholl et al. (1969) estimated maximum sedimentation rates to be only 1.6 cm/l ka. Thicker calcitic marl deposits formed in the last 3 ka, when the rate of relative sea-level rise decelerated, in areas where environment remained constant. The lower (southeastern) Everglades, adjacent to

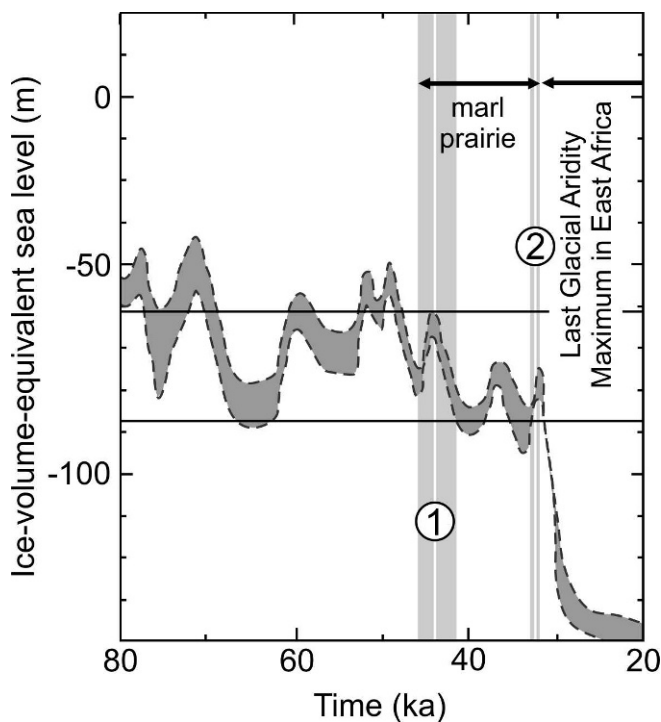


FIGURE 8—Ice-volume-equivalent sea level at 80–20 ka (modified from Lambeck and Chapell, 2001); dashed lines = upper and lower limits. Vertical gray bars highlight the radiocarbon ages of the organic-rich clay beneath the palustrine limestone (1) and of the top of the palustrine limestone (2); the two horizontal lines indicate the sea-level confidence interval at 43,983 +1,907/–1,540 ^{14}C yr BP.

Card Sound, has >1.5 m of calcitic marl that formed over the past 3 ka (H.R. Wanless, personal communication, 2009). Although this equates to a minimum of 0.5 m/1 ka, it is only half as much as the current findings. Experimentally calculated sedimentation rates for microbially precipitated carbonate in the southern Everglades marl prairies (Merz, 1992; 10–24 cm/1 ka) are four times lower than our findings.

The different sedimentation rates of the Tanzanian and Everglades marl prairies might be explained by the high porosity of the Tanzanian marl-prairie sediments, which is due to more complete calcification of the microbial community. In the Everglades marl prairies, calcified cyanobacterial tubes disintegrate rapidly into calcite mud with low porosity, and laminated fabrics are restricted to the top few centimeters of the sediment (Merz, 1992; Merz and Zankl, 1993). Calcite-crystal nucleation outside the cyanobacterial filaments is caused by inorganic calcium-carbonate precipitation (encrusted sheath *sensu* Riding, 1977) and occurs in many travertines due to temperature increase and CO_2 degassing at groundwater outlets. In marl prairies, however, encrustation of cyanobacterial sheaths is insignificant because the water is very shallow, flows over large distances, and is, therefore, well equilibrated with the atmosphere (Merz, 1992). For *Scytonema* and *Schizotrix*, Merz (1992) has shown that cyanobacterial calcification in marl prairies is controlled by physiological activity (impregnated sheath *sensu* Riding, 1977) and depends on the sheath structure of the filament. The sheath of *Scytonema*, for instance, is differentiated into two distinct layers (inner and outer sheath). In the Everglades marl prairies, calcification of *Scytonema* is weak because it is restricted to the outer sheath of the filament. In the Tanzanian palustrine limestone, increased carbonate impregnation of cyanobacteria is documented by the preservation of articulated boxwork fabrics in pristine *Scytonemataceae* mats (Figs. 3E, F), as well as by the exceptional preservation of single, coccoid cyanobacterial cells that lack any calcite overgrowths (Fig. 3B). Strengthened calcification of cyanobacteria could indicate high light stress (VanLiere and Walsby, 1982; Merz and Zankl, 1993). Higher

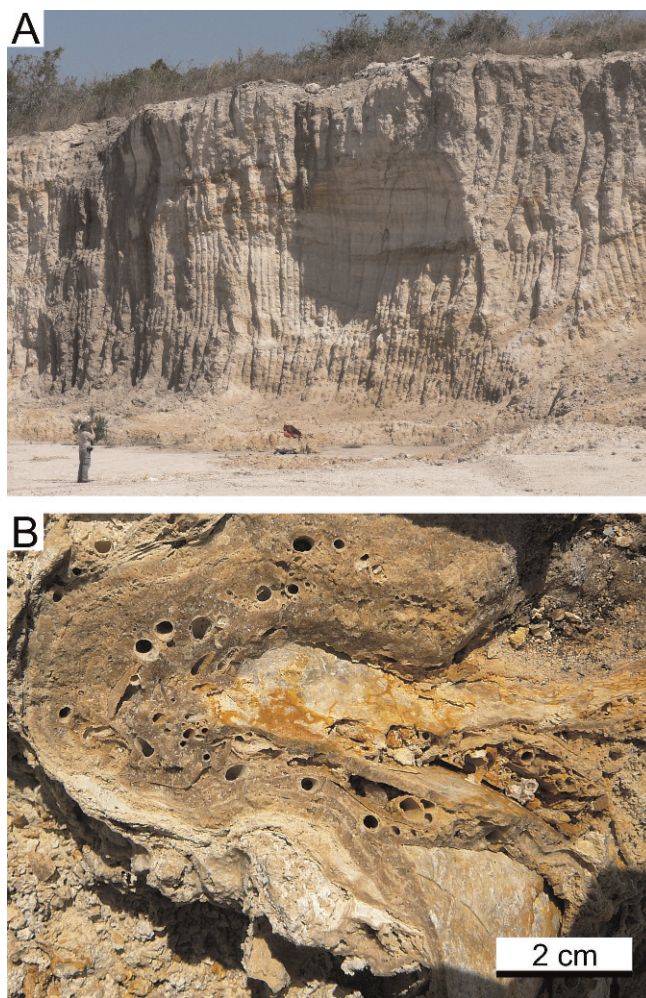


FIGURE 9—Carbonate accretion at Mbanja, Tanzania. A) Thick palustrine limestone deposits. B) Molds of broken reedlike plants in a shriveled periphyton mat. The bending of the well-calcified microbial mat is interpreted as the result of shrinkage owing to desiccation during the dry season. It is assumed that the highly porous carbonate crusts retained water from rainfall during the humid seasons, and this accounts for the accretion of a thick-body palustrine carbonate.

light stress for the Tanzanian periphyton may have resulted from the proximity to the equator and may have increased during the last glaciation due to a reduction of atmospheric water vapor and CO_2 concentrations at low latitudes in Africa (Gasse, 2000).

Carbonate soil crusts that develop by desiccation in seasonally flooded wetlands allow only slow seepage of water and impede rapid drainage during arid seasons (Wright and Platt, 1992; Davies et al., 2005). In the Everglades marl prairies, however, crustlike features disappear during the wet seasons when the laminated cyanobacterial mats become immersed by the rising fresh water. In accordance with Merz and Zankl (1993), we suggest that the fossil periphyton crusts from East Africa were more robust because of their strong calcification and, therefore, retained water from rainfalls during the humid seasons (Fig. 9B). Thus, the periphyton habitat was self preserving and allowed the limestone body to accrete for about 10 ka (Fig. 8).

CONCLUSIONS

Palustrine carbonates from coastal Tanzania meet the criteria of an Everglades-type marl prairie in having (1) a short hydroperiod during the rainy season, (2) desiccation during extended drought, (3) reedlike vegetation, and (4) a calcitic substratum produced by calcareous periphyton in a shallow lacustrine environment. This unusual setting

for carbonate production has so far been reported only from the recent of the Florida Everglades. The Tanzanian marl prairie presented here is the first record of a marl prairie from outside the Everglades. Carbonate production started at ca. 44 ¹⁴C ka during a phase of falling eustatic sea level and tectonic uplift in southern coastal Tanzania that initiated a drop of the groundwater table. The marl prairie dried up at ca. 33 ¹⁴C ka at the beginning of the LGAM in equatorial East Africa. The African example demonstrates the sensitivity of an Everglades-type marl prairie to seasonal as well as long-term climatic changes. Therefore, fossil marl-prairie deposits have a high potential to provide useful information on the water balance for paleoenvironmental and paleoclimatic reconstructions.

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