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Features of channel margins in the Okavango Delta

T.S. McCARTHY, K.H. ROGERS, I.G. STANISTREET, W.N. ELLERY, B. CAIRNCROSS & K. ELLERY
University of the Witwatersrand, RSA

T.S.A. GROBICKI
131 Dundalk Avenue, Parkview 2193, RSA

ABSTRACT

Joint sedimentological-botanical studies have been initiated in the perennial swamps of the Okavango Delta-fan, Botswana. It has been recognized that a knowledge of the interface between the active channel and the adjacent swamp vegetation is crucial in the understanding of the dynamics of the Delta. This interface was studied in both active channels and abandoned channel counterparts. Three types of channel margin have been recognized. The first is *Miscanthus junceus* dominated, erosive and generally occurs on cut banks of channels. The second is *Cyperus papyrus* dominated, with roots and rhizomes stabilizing the peat bank. In both cases, the organic material forms a vertical to overhanging edge which is probably slightly permeable and within which suspended matter is deposited. The transition from fine sand deposited in the channel to the peat which forms the bank is very sharp with a minimum of intercalation. The third type of margin is associated with mild flow separation in the channel which leads to the development of edge-parallel bars in the channel, across which vegetative encroachment commonly occurs. These bars are often themselves vegetated by submerged species and are characterized by pronounced intercalation of peat and sand.

All types of margin show stability over the life of the channel notwithstanding the rapid vertical aggradation of the channel systems and the tendency of plants to encroach into the channels. This stability reflects a dynamic equilibrium between plant growth and water flow. The equilibrium is maintained through most of the active life of a channel by virtue of the fact that the seasonal fluctuations in water level are buffered in this region of the Delta

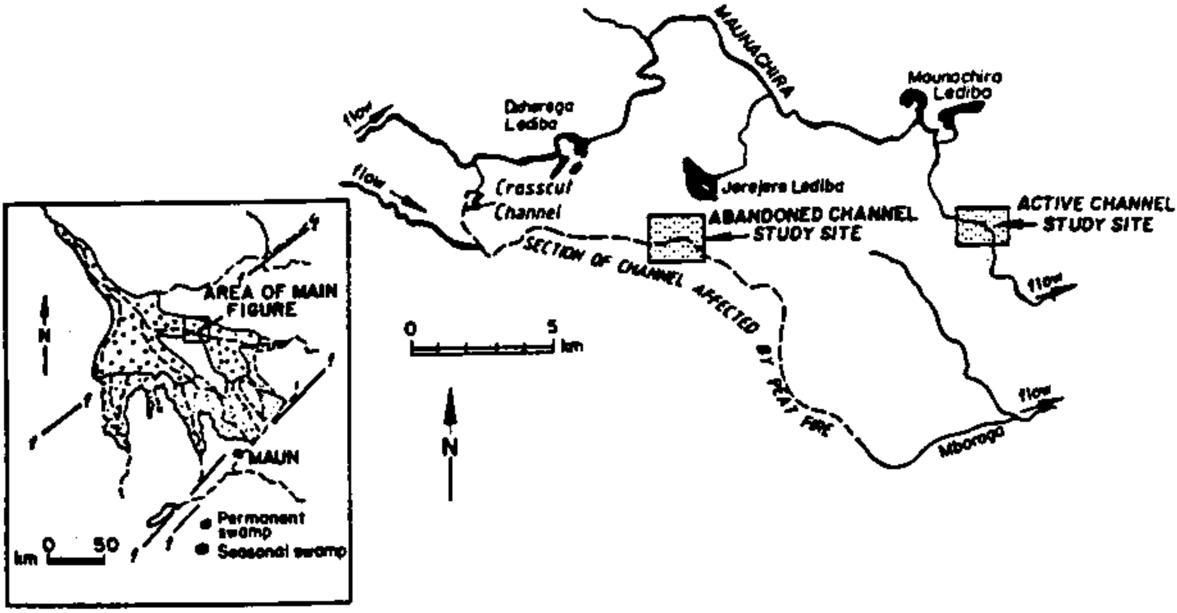

Figure 1. Location of study areas

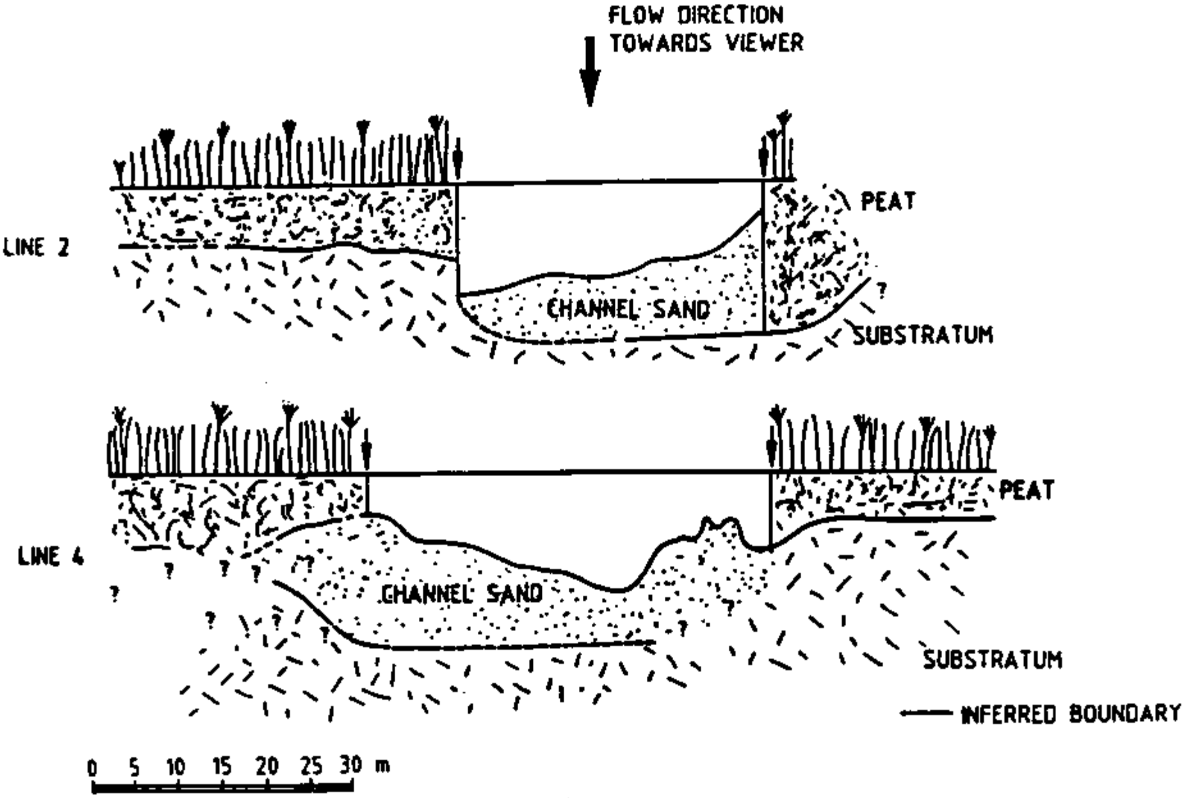

Figure 2. Profiles across the active Maunachira channel

channel (Fig. 1) with a view to documenting the structure of channel margins.

Depth profiles across the Maunachira channel are illustrated in Figure 2. The channels are characterized by near vertical margins and, while the substratum beneath the peat is essentially flat or gently undulating, the

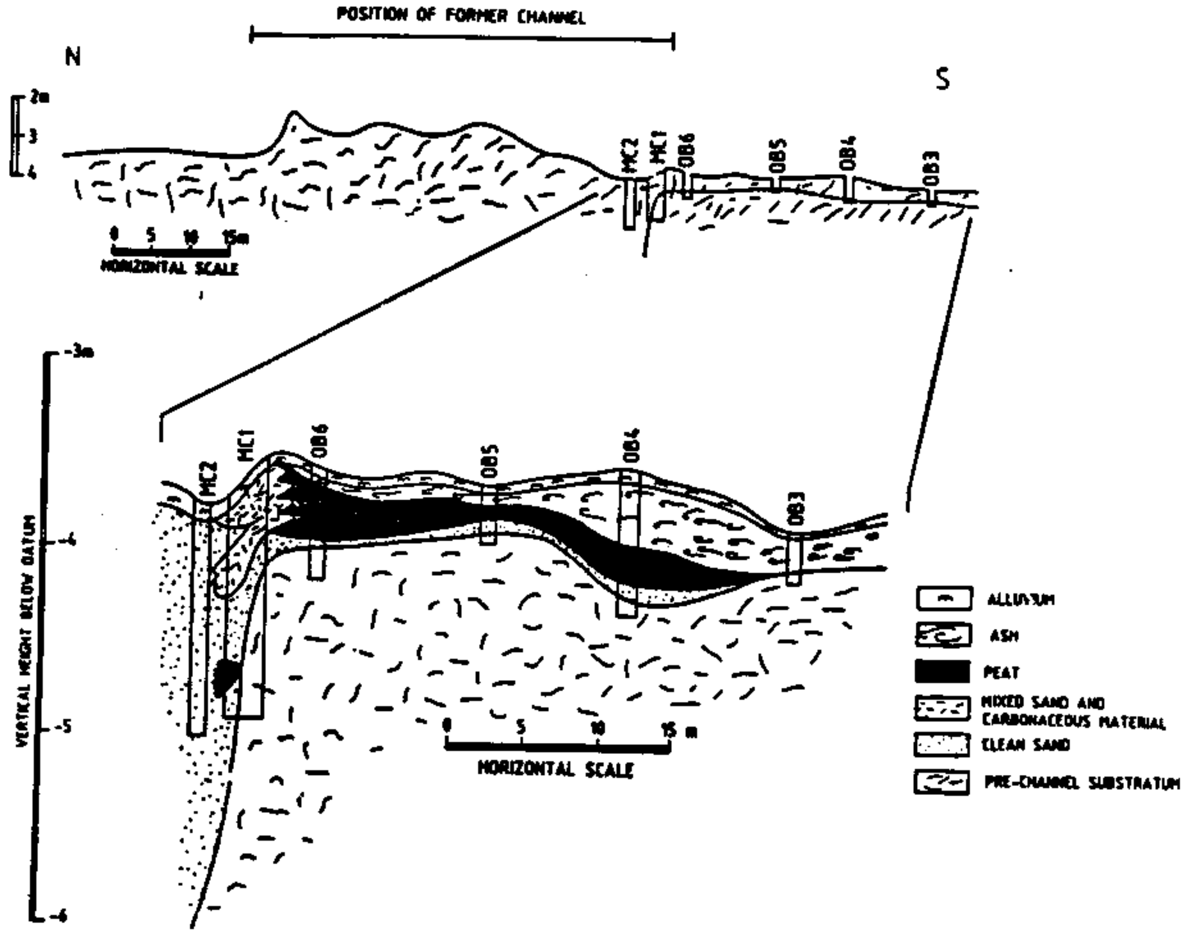

Figure 3. Surface and subsurface profiles across the abandoned Nqoga channel

channel bed tends to be more irregular. Excavations and surface profiling carried out on the now abandoned, but formerly comparable, Nqoga channel (Fig. 3) (McCarthy et al. 1986, McCarthy et al. 1987) made it possible to distinguish between the older, pre-channel substratum and active channel sediment, a distinction not possible in the case of the active channel. This indicated that the Nqoga channel was originally erosive, but that the incised channel was subsequently filled with sand (Fig. 3). It is probable that the section of the Maunachira channel studied is at present experiencing filling and the underlying portion of the profiles shown in Figure 2 have been interpreted on this basis.

The channel bed of the active Maunachira consists of fine to very fine, pure, quartz sand (Fig. 4) which is fairly well sorted (average grain size, 0.31 mm or 1.6 ± 0.6 θ). Transportation occurs via downstream migration of lobate sand waves with avalanche faces often in excess of 1 m high at channel centre. Small-scale ripples migrate up the broad, stoss faces of the sand waves. The suspended load is small, as judged by water clarity, but it is evident from studies of peat that this suspended load is nevertheless very important.

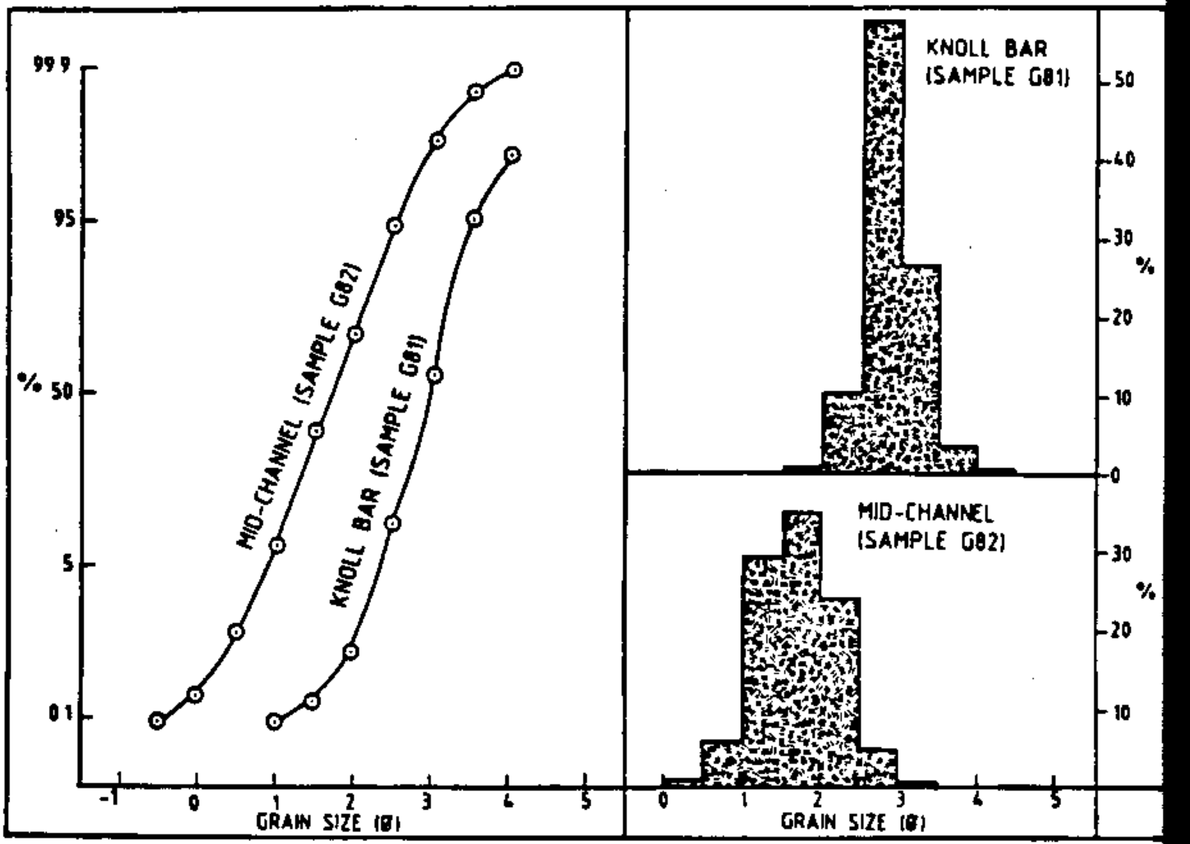

Figure 4. Size distribution of a typical channel bed sand and sand from a knoll bar

Water depth is typically 3-4 m in the channel (Fig. 2), and surface flo velocity at channel centre is of the order of 0.5 m per second.

The surface vegetation flanking the channels, particularly on the inner sid of channel bends, consists of papyrus with an understory of the fern *Thelyp teris interrupt* which are dominant adjacent to the channel. These give way t *M. junceus* dominated communities away from the channel and on cut ban bends. The dense plant growth maintains a water level gradient away fro the channel (Wilson & Dincer 1976, Wilson 1973, McCarthy et al. 1987 and surface flow velocity of 2.5 cm/s was recorded perpendicular to t Maunachira channel at the study site.

The upper surface (c. 30 cm) of the channel flanking areas consists of submerged zone of interlocking papyrus and *M. junceus* rhizomes in a mat *T. interrupt* roots. A loose black sludge, consisting of fine organic detritus a clay forms the matrix of this living plant material. Detailed analysis of sample of this sludge yielded an organic material content of 31.6% (d weight). The inorganic fraction, amounting to 68.4%, was made up by qua (6%), kaolin (45.6%), some inorganic iron and inorganic components plant origin (largely amorphous silica). Beneath this the number of livi roots declines with depth and the peat, consisting of dead plant material in t black matrix, becomes more compact.

THE STRUCTURE OF CHANNEL MARGINS

Central to the dynamics of channel systems are the interactions which take place at the interface between the open water of the channel and the adjacent swamp areas. The character of this interface was examined in active channels, while observations made in the abandoned Nqoga channel were used to provide additional information.

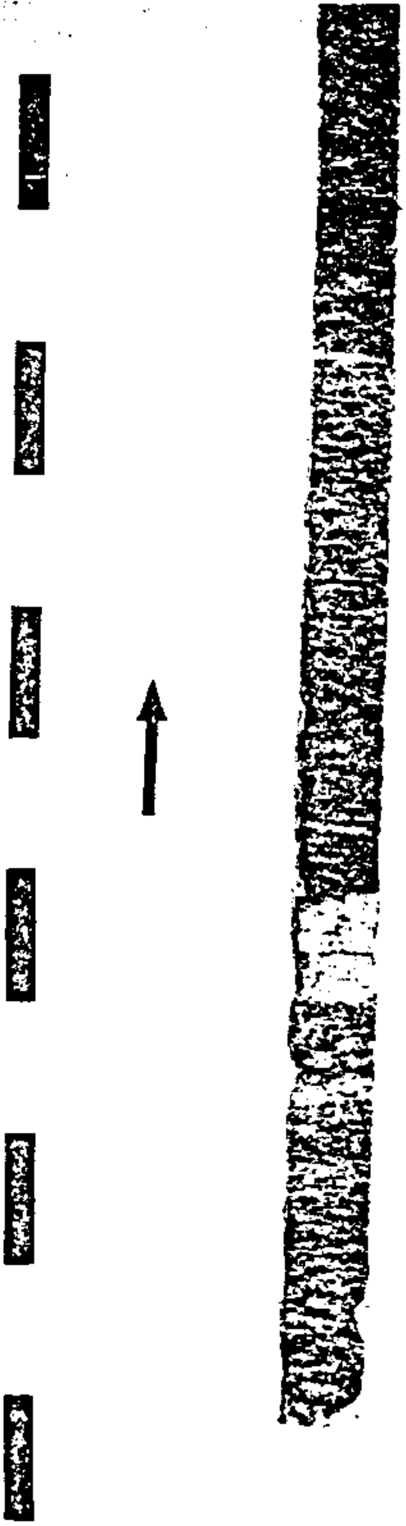

Figure 5. Core through a knoll bar (10 cm scale bar intervals)

Sedimentological features of the channel margin

Detailed profiles shown in Figure 2 indicate that the channel bed at th margins of the channel may reflect either net erosion or net deposition wit respect to the substratum beneath the peat. Large-scale bed forms ma develop close to the channel edges. These are hummocky shaped bars, whic we term knoll bars. They are typically about 10 m in length, 4 m wide an have a maximum crest height of about 2 m. They elongate parallel to th channel, with no pronounced avalanche face. They are often vegetated particularly in areas of reduced velocity, in which case they tend to approac the water surface. The submerged species *Otellia ulvifolia* and *Potamogeto thunbergii* are characteristic of such bars.

Similar knoll bars were excavated in the Nqoga channel (Fig. 1) and sho plane lamination conformable with the bar topography except on the down stream, bank side which showed stacked, thin (2 to 5 cm) sets of planar cros laminations. A vegetated knoll bar in the active channel was cored to a dept of 1.5 m. This showed interbedding of clean, channel-edge sand (Fig. 5) an mixed layers consisting of plant matter and sand. Grain size of the sand i variable depending on the position and character of the bar. The unvegetate knoll bar on the Nqoga channel had an average grain size of 0.32 mm (1.65 0.6 Θ) while in contrast the vegetated knoll bars in the Maunachira channe typically have grain size of the order of 0.14 mm (2.85 ± 0.4 θ) (see Fig. 4) The vegetation appears to act as a stabilizer and trap for fine sand and organi debris, producing interbedding of sand and carbonaceous material.

Where flow is more rapid and knoll bars are not developed, two types o channel edge are recognizable. On outer bends, the channel margin is nearl vertical, the bed somewhat deepened, and the margin is formed by livin vegetation which stabilizes underlying peat. On inside channel beds, san deposition tends to dominate and the channel shallows more graduall towards the near vertical but shallower vegetated channel margin. Limite interbedding of sand and organic matter may be a characteristic feature o these inner bank sequences.

Botanical features of channel margins

The inner margins of bends tend to be dominated by papyrus, the rhizomes o which extend out into the channel. As the rhizomes increase in length, wate flow and increasing weight seem to cause them to be drawn downstream an to sink and they become forced against the bank (W. Ellery, in prep.). An interlocking mat of rhizomes and roots develops against the peat surface and protects it from reworking.

The outer banks tend to be dominated by *M. junceus*. This species ha many short rhizomes with closely spaced culms. Near surface, the living *M junceus* forms a dense mat of upright rhizomes and culms which are rooted i

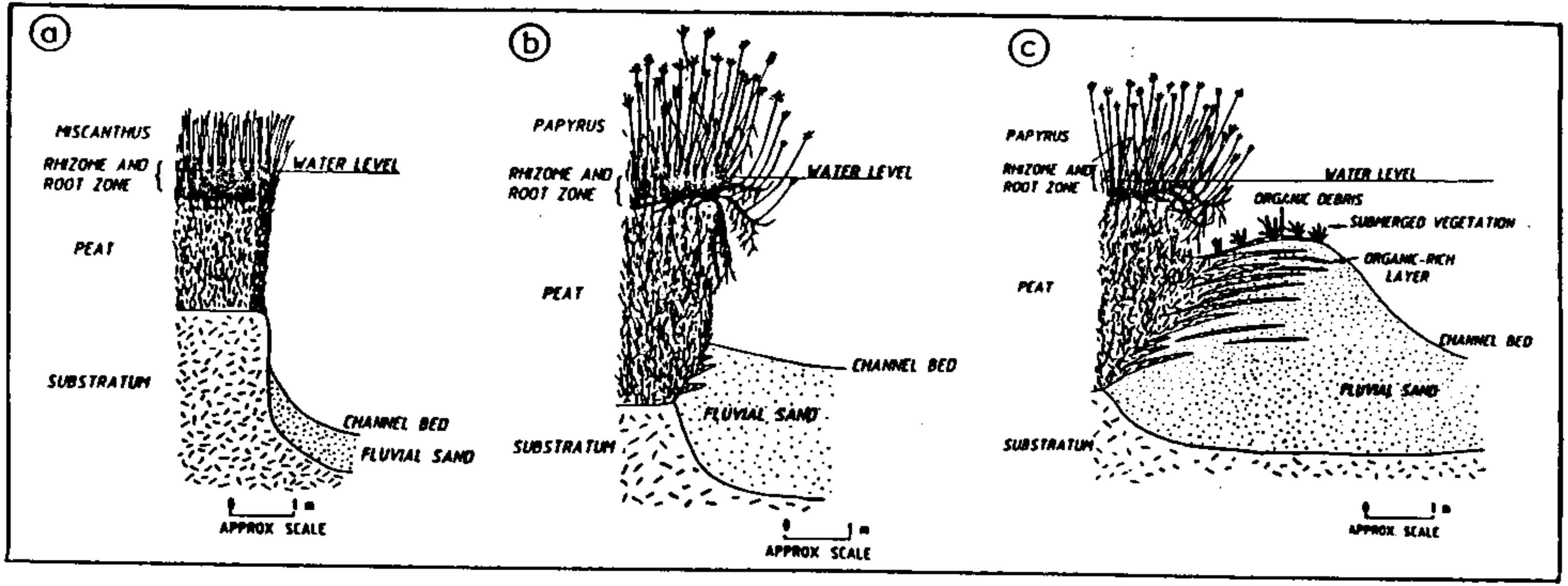

Figure 6a. Schematic section through a cut-bank channel margin; b. Schematic section through an inside bend; c. Schematic section through a channel margin with a knoll bar

dead rhizomes and culm bases of past communities. Together, both the living and dead material form an upright wall which is not easily eroded.

DISCUSSION

Previous work suggests that individual channel systems in the upper Delta undergo rapid vertical aggradation (McCarthy et al. 1986), yet highly sinuous channels can persist for long periods (decades) without any change in shape or width (Wilson 1973). This is remarkable when one considers the rhizomotous growth habit of papyrus, which is typical of species adapted to encroaching into poorly or unvegetated areas such as an open water channel. This implies that there exists a dynamic equilibrium at the channel margins which regulates both vegetative encroachment and erosion of the underlying organic material.

The channel margin is a feature which separates the very different processes operating in the channel and in the adjacent swamp. The most significant feature of this interface is the water velocity contrast. The interface itself is probably permeable and permits through flow of water, albeit very slow, certainly very much less than the 2.5 cm/s recorded for surface flow in the swamp adjacent to the Maunachira. This would result in the peat acting as a sedimentary baffle, which promotes rapid deposition of fine particulate material (both organic and inorganic) in the peat adjacent to the channel. The more rapid growth of plants on the channel margins compared to back swamp areas can probably be attributed to continuous supply of nutrients adsorbed onto these particles. The width of the zone of penetration of particulate materials is not known, but is probably measured in tens of metres.

Sand grade material is transported in the channel as traction and saltation load and therefore is not transported into the swamp areas. Only the minor suspension load can ingress into the flanking peat. This infilling of the peat by fine sediment in time must gradually reduce the permeability of the peat. This process is probably also progressive with a gradual decrease in permeability with depth in the peat, due to increasing age.

The differences in growth habits of papyrus and *M. junceus* tend to result in their occupying different positions on a channel. The short, non-creeping rhizomes of *M. junceus* with their tightly packed culms present a resistant phalanx, which retains its mechanical strength long after death. In contrast, the long, flexible rhizomes of papyrus are susceptible to breakage in high water flows. Hence, *M. junceus* tends to dominate outer banks where flow is rapid and papyrus inner banks where flow is slow. It appears that encroachment of papyrus from inner banks is curtailed by the fact that as the rhizomes extend outwards into the channel they offer greater resistance, and are forced back towards the bank and become deeply submerged. Growth is inhibited and the rhizome eventually dies and is broken off and carried away (W. Ellery, in prep.). Nevertheless, the mass of rhizomes and roots serves to reduce water velocity at the channel margin and this protects the peat from erosion.

During vertical aggradation of a channel system, the sand accumulates primarily on the floor of the channel, while the vegetation flanking the channel roots in the dead organic material of former generations of plant which have been augmented by fine detritus. At any stage, this organic material forms a near vertical wall flanking the actively flowing channel. The transition from channel sands to organic rich sediment is therefore extremely abrupt. Just how abrupt is emphasised by the excavations carried out on the abandoned section of the Nqoga. Along the section line shown in Figure 3, peat thickness must have been in the region of 4m while the channel was still active based on observations from presently active channels. The peat fire which passed through this area destroyed virtually all of the organic material, leaving a residue of burnt clay and compacted peat. The elevation of the ground surface does not change away from the channel, and thickness of surficial cover is now essentially the same right up to the channel margin, where a limited zone of intercalated sand and organic material is developed (Fig. 3). The peat therefore probably presented near vertical bank to the channel as indicated on Figure 3.

Flow separation which may occur either on river bands or other channel margin irregularities results in the growth of knoll bars. Fine sand and organic detritus accumulate on these bars as they enlarge. Plants take root, further enhancing their growth. Ultimately papyrus may encroach across them from the lee side towards the channel.

Diagrammatic reconstruction of the structure of three basic types of channel margin are shown in Figure 6. In each case, the interface between channel sediment and peat is remarkably abrupt. These reconstructions relate to a steady state condition where the channel margin is at equilibrium. It is probable that this state persists for much of the active life of a channel system.

The interaction between plant growth peat formation, sediment entrapment and water flow is central to this remarkable equilibrium which exists on channel edges in the upper Delta. Large-scale seasonal changes would tend to disrupt such an equilibrium. However, in the case of the upper reaches of the Delta, seasonal variations in flow are strongly damped by the storage of water released from the channels by overspill and hence dramatic changes in water levels and flow velocity do not occur (Wilson & Dincer 1976, UNDP 1977). Seasonal variations in sediment characteristics would likewise be damped by the filtration of the water by peat and vegetation. Therefore, rapid fluctuations in nutrient supply would also be damped. Hence, there are no major seasonal disturbances of the channel margin equilibrium.

CONCLUSION

This preliminary investigation of channel margins has provided some insight into the structure of channel margins and the processes which operate along these margins, which contribute to their long-term stability.

Perhaps the most remarkable aspect of the channel margins is the rapid transition from peat to channel bed sediment (e.g. Fig. 6b). Significant interlayering is confined to knoll bars which occasionally develop close to channel margins in areas of reduced flow velocity. A vertical persistence of this transition, during vertical aggradation, indicates limited lateral movement of the interface. The well-sorted bed load moves by traction and saltation and deposits only on the channel beds. Lateral fining of sediment is not a feature of channel margins; rather fine sediment is deposited within the peat flanking the channels. The suspended load is, however, small which ensures that the channel margins are volumetrically dominated by organic material rather than by inorganic detritus. Had the suspended load been significantly greater, the channel banks would in all probability have been dominated by fine sediment with low permeability and similar to the anastomosed channels described by Smith & Smith (1980) from Alberta. The character of the Okavango Delta would have been quite different as a result.

The peat-channel interface is in equilibrium with water flow in the channel. The encroachment of plants into the channels is controlled by flow velocity and only occurs in areas of reduced flow such as in the lee of advanced knoll bars. Elsewhere, protruding rhizomes are broken off by the flow at the same rate at which they are produced. The living plant material (rhizomes and roots) also serves to protect the peat on channel margins from erosion.

Perhaps the most important underlying aspect of the long-term stability of the channels in the upper Delta is the constancy of the flow regime. This constancy is probably a consequence of the buffering of seasonal variations in water level, due to flood season loss of water to the peat swamps and dry season return flow to the channels. This buffering is in turn only possible because of the very low topographic gradients and low suspended sediment load. It appears that, as a consequence of this stability, plant growth and water flow are involved in a constant interaction in which living rhizomes become deeply submerged, die, decay and are broken off at the same rate at which they are produced. Present detailed studies are investigating the relationships between plant demography and flow conditions (W. Ellery, in prep.).

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