5 CHARACTERISATION OF MIRES

5.1 The Natal Mire Complex (NMC)

In the tropical coastal plain of northern Natal extensive coastal mires occur together with bound interdune mires. The name Natal Mire Complex is therefore used for this assemblage of mires (Fig. 5.1). The NMC describes a broad area in which mires are widely distributed in an area of reworked Cainozoic sediments representing a variety of depositional environments, including shallow marine/beach, aeolian, lagoonal, paludal and fluviatile settings. These depositional environments represent the dominant physiographic elements of the present-day Zululand coastal plain of which the NMC forms an integral part. The Complex in South Africa is confined between latitudes 31°05'S and 26°52'S (Fig. 4.1) from where it extends into Mozambique. From the southern end to Richards Bay (28°48'S), the NMC never extends further inland from the coast than approximately 15 km. From here, the Complex starts to broaden to 35 km at Black Rock (27°08') and 68 km at Ponta Milibangalala (26°27') in southern Mozambique. The NMC is divided into a narrow southern and a broad northern belt, which hug the coast and coalesce at Richards Bay.

5.1.1 Geomorphological setting.

The peat was deposited in depressions parallel to the coast between Quaternary and Holocene coastal dune cordons, forming irregular but elongated discrete bodies in the interdune areas (at C in Fig 5.1, Fig. 5.2 A). In the area surrounding the St. Lucia Lake system - Mapelane (at A in Fig. 5.1) to just south of Sodwana (B in Fig. 5.1) - the peatlands broaden out into large swamp and marsh lands with grasses, sedges and ferns dominant (Table 5.1; Fig. 5.3B, D). Locally, mangrove forests also represent the primary peat formers (A in Fig. 5.1; Table 5.1; Fig. 5.3A). In these peatlands, although large in area, the peat is generally not as thick as the interdune peats; a maximum thickness of 2 m has been measured.

Figure 5.1 The northern part of the Natal Mire Complex (NMC). The localities marked are: (A) Mapelane, (B) Sodwana/Mgobozeleni, (C) Black Rock and (D) Amanzamnyama/Siyadla.

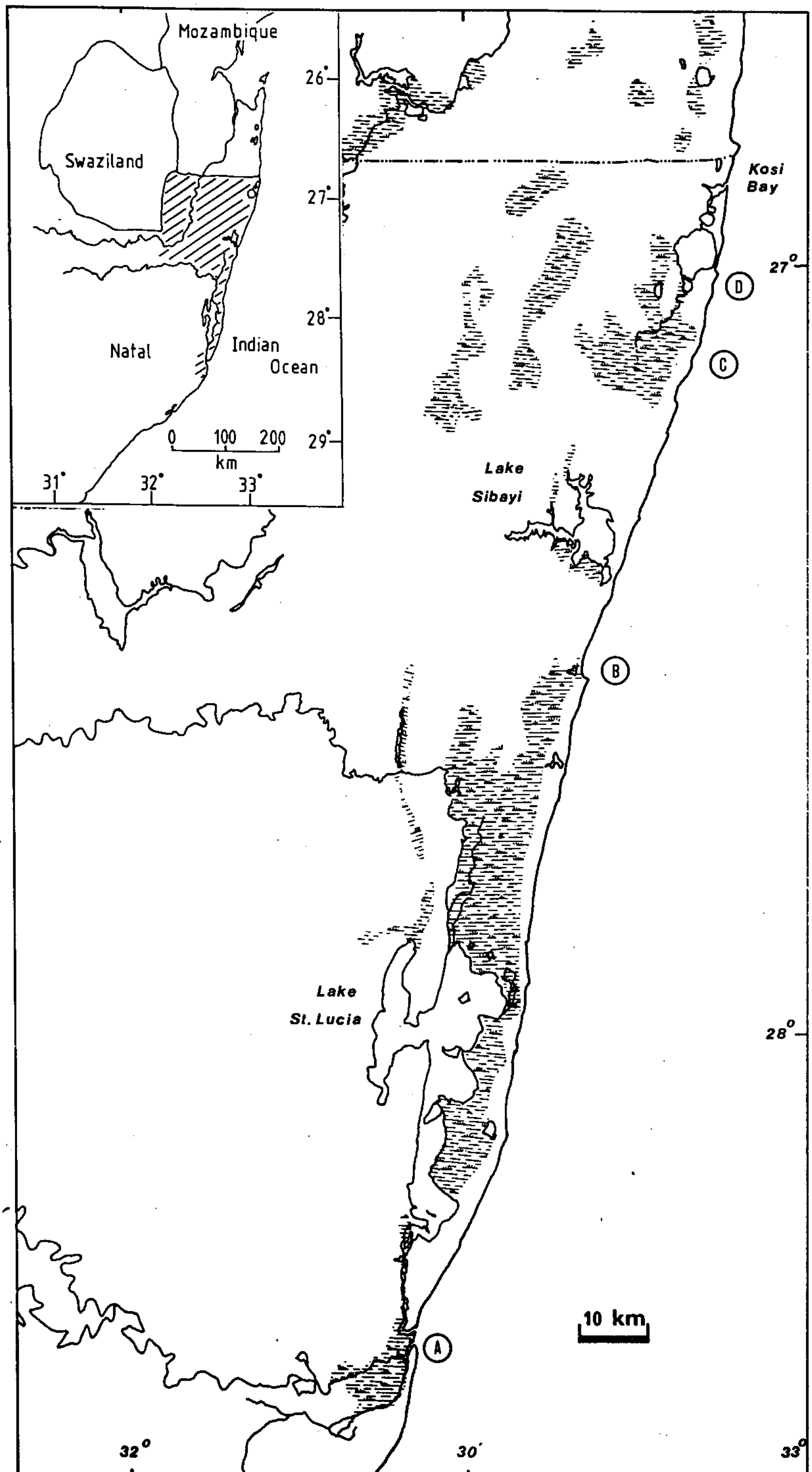
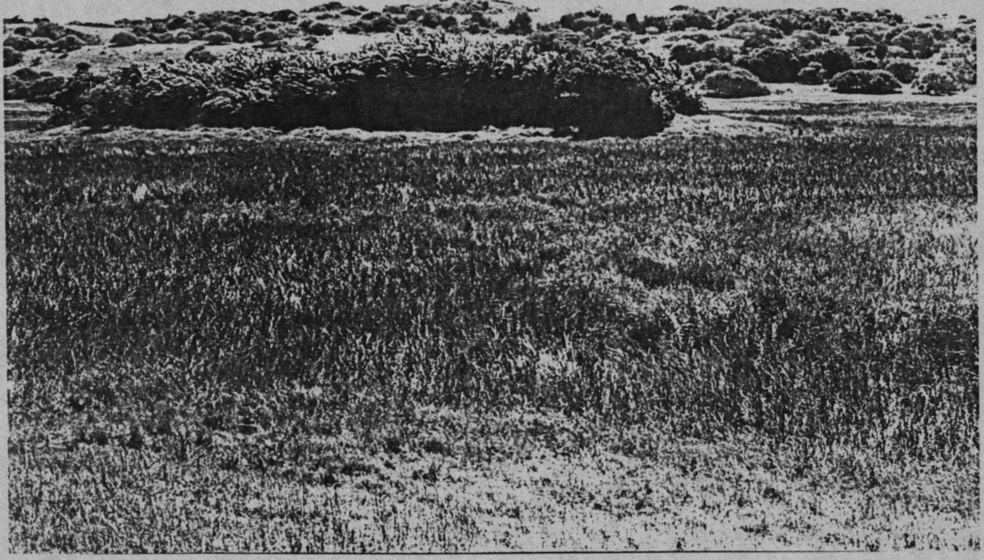


TABLE 5.1 THE MOST COMMON PEAT FORMING PLANTS FROM THE DOMINANT PEATLAND TYPES IN THE NATAL MIRE COMPLEX

FOREST MIRE (FS)	MANGROVE SWAMP (MS)	SEDGE/REED MIRE (SR)
Syzygium cordatum	*Rhizophora mucronata*	*Phragmites australis*
	Bruguiera sp.	
Ficus sp.	*Ceriops tagal*	*Scirpus* spp.
Hibiscus tiliaceus	*Avicennia marina*	*Typha capensis*
Rauvolfia caffra	*Elephantoriza* sp.	*Cyperus isocladus*
Voacanga thouarsii		*Cyperus* spp.
Strelitzia nicolai		*Schoenoplectus corymbosus*
Raphia australis		*Nymphaea* sp.
Barringtonia racemosa		*Polygonum pulchrum*
Herbaceous plants		*Echinochloa* spp.
Stenochlaena sp.	*Thelypteris* sp.	*Potamogeton* spp.
	Acrostichum aureum	*Leersia hexandra*
		Juncus kraussii
		Mariscus congestus

FIGURE 5.2



A). Interdune sedge/reed mire (27° 07' S / 32° 49' E) near Black Rock. Note tree-covered island in the middle distance. Halfway towards the island the peat already reaches a thickness of more than three metres.

B). Transition between Raphia (back ground) and swamp forest vegetation of the Siyadla region (27° 03' S / 32° 48' E). The tree in the foreground is *Ficus tricopoda*.

FIGURE 5.2

C). A view of the peat surface inside a swamp forest. Note the curled-up, dried leaves. Most of these will be broken down by detrivores to smaller dark humus particles in the surface litter zone, but some leaves will be taken up into the peat in this form to become part of the degradofusinite component. Most of these leaves are from *Syzygium cordatum* (small) and *Ficus tricopoda* (large) trees.

D). A view into the Raphia australis mire. The density of the stand prevents most leaves (reputed to be the largest in the world) and dead trunks from falling directly to the surface, with the result that it takes a long time before this material becomes available to the peatification process.

FIGURE 5.3

A). Mangrove/Swamp forest transition. Although still brackish, the water is too fresh for the mangrove species and the peat formers here are predominantly *Ficus tricopoda* (here with extensive above-ground standing roots) and *Barringtonia racemosa* (30cm high seedlings in lower right-hand corner of the photograph). note the absence of any understorey vegetation and abundance of open water.

B). An oblique aerial view of part of the 45 000 ha Mkuse swamp (27°45'S/32°32'E). Note circular species colonialization patches that later coalesce to form an extensive single species colony in a mire or part of it. Note permanent hippopotamus trails that tend to skirt round the clusters of denser vegetation (here the bull rush, Typha capensis).

FIGURE 5.3

C). A view of the dense understorey of a typical freshwater swamp forest made-up predominantly of ferns and broad-leaf grasses.

D). A near-vertical view of the hydroseral zonation in a NMC sedge/reed mire. The open water here is almost entirely covered by water lilies. Hippos manage to keep open a path along the deepest parts. The water lilly makes way for reeds, followed by sedges, followed by grasses as more open water is invadeded by peat and the substrate becomes increasingly "dry". Note abundant game tracks of water loving antelope in the dense grass stands along the top of the photograph.

5.1.2 Vegetation.

The flat undulating plain behind the high Recent coastal dune cordon, although much altered by slash-and-burn farming practices and forestry activities, is typified by an open grassy palm-veld, mainly *Hyphaene natalensis* and *Syzygium cordatum* (Acocks, 1975; Moll, 1979).

In this area the peatlands support primarily herbaceous plants such as grasses, sedges, ferns and other plants that are capable of existing in wet, often pond-like, nutrient-poor conditions (Figs 5.2A, 5.3C and D).

Away from the coast this vegetation phases into relatively short, tangled jungle of the Sand Forest in which lianas, palms and *Strelitzia nicolai* are conspicuous.

5.1.3 Field characteristics of the peat.

In order to better illustrate the field characteristics of these mires the following localities (Fig. 5.1) were investigated in some detail;

A - Mapelane

B - Sodwana

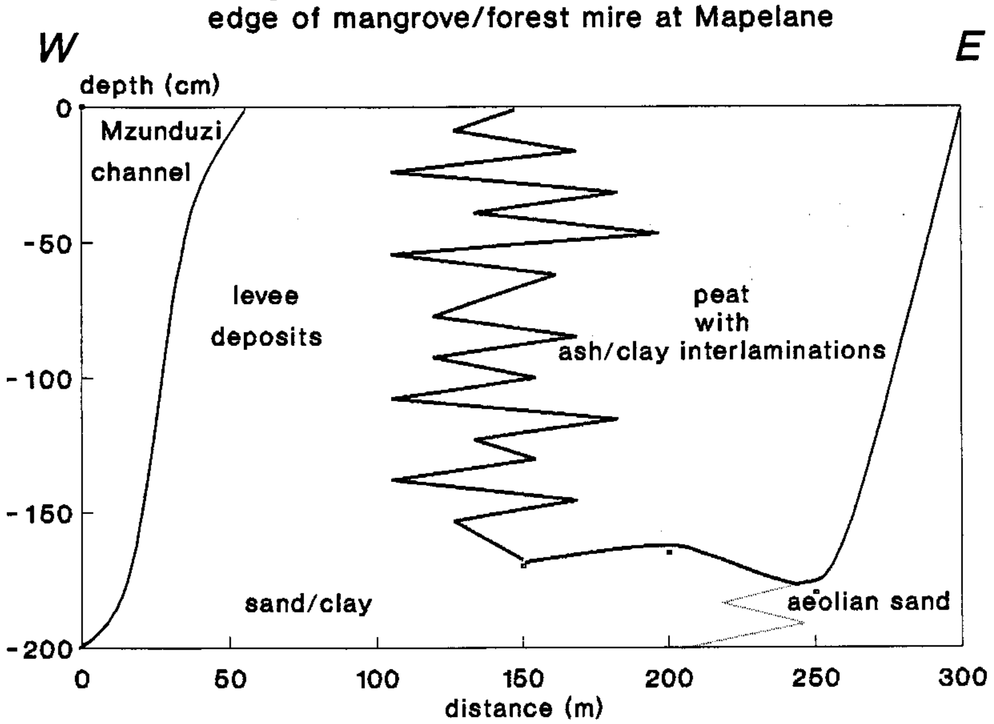
C - Black Rock

D - aManzamnyama / Siyadla.

Figure 5.4 is a schematic cross section of the eastern edge of the mire at Mapelane (Fig. 5.1 locality A) orientated roughly normal to the Indian Ocean. Note that the peat laps onto the base of the Holocene coastal dune cordon in the east and interdigitates with the sands and clays of the Msunduzi and Mfolozi Rivers and their palaeochannels.

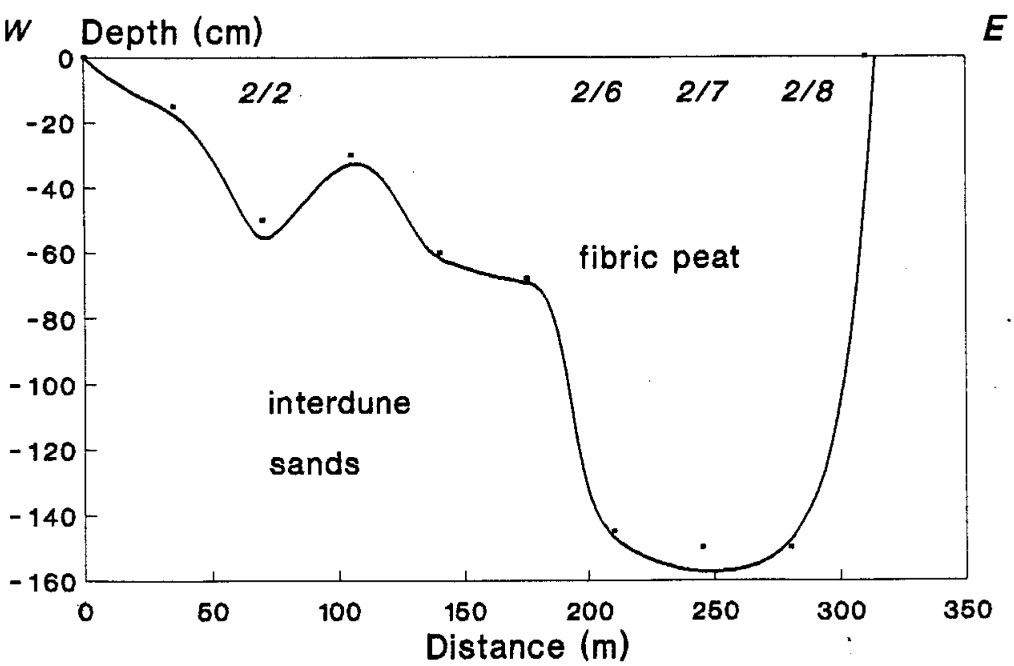
A cross-section of a typical interdune mire at Mgobozeleni (Fig. 5.1 locality B) exhibits the relationship between the swamp forest peat and the associated dune field (Fig. 5.5). Peatlands in the Black Rock area (Fig. 5.1 locality C) exhibit cross-sections similar to the one at Mgobozeleni.

Fig. 5.4 Cross section through eastern edge of mangrove/forest mire at Mapelane



2732 AD/12 (28 28'S; 32 24'E)

Fig. 5.5 Cross section through a Swamp Forest mire (Mgobozeleni)



2732 DA/2 (27 32'S; 32 39'40"E)

See Figure 5.1 for localities of these two profiles. The numbers 2/2 to 2/8 refer to boreholes along the line of the profile (2/1 and 2/3 - 2/5 are omitted for the sake of clarity).

5.1.4 Peat petrography.

The petrographic study of peat only started fairly recently, adding greatly to a better understanding of the transition from peat to coal. Most of these studies have, however, been done on peat from tropical and sub-tropical swamp environments in the Americas (Cohen, 1973; Cohen and Spackman, 1977, 1980; Staub and Cohen, 1978, 1979; Cohen et al., 1985).

To date petrographic studies on African peats are largely of an introductory nature and have been carried out only for Senegal, Togo, Rwanda/Burundi and South Africa (Chateauneuf et al. 1991; Smuts, 1992). The petrographic composition of peat is attributable to a number of successively dependent aspects, namely:

* the climate at the time of deposition,
* ecological conditions in and around the peatland
    - available oxygen
    - groundwater level
    - rate of groundwater flow
    - pH of the system
    - external influences (marine incursions, erosion, sedimentation, fire, human intervention),
* plant communities responsible for peat formation, and
* the stage of humification (diagenesis).

Present-day peatforming environments and plant associations are subdivided into four principal groups by Stach et al. (1982);

1) open water with abundant allochthonous material; peat and organic mud form from floating and sub-aquatic plants.
2) open marshes with sedges, reeds and herbaceous vegetation.
3) forest/bush swamps rich in woody vegetation.
4) ombrogenous moss bogs.

Groups 1 to 3 belong to low-moor (fen) peatland types (influenced by groundwater) which are usually related to river valleys, lakesides and coastal lowlands. Group 4 is of the high-moor type (bog) and its only source of water is rainfall.

5.1.4.1 Botanical composition.

Based on their botanical composition, the following major peat types in the NMC were recognised by visual and microscopic inspection (in order of dominance); (1) sedge-reed peat, (2) freshwater swamp forest (hard wood) peat, (3) mangrove peat and (4) *Raphia* swamp peat. Minor peat types recognised (apart from peats representing the sub-types in Table 5.2) were undifferentiated, highly humified peat, various transitional peats and *Nymphaea* peat.

Sedge-reed peats are generally hemic (34-67% fibre content) to fibric (more than 67% fibre), hard wood peats are hemic to sapric (less than 34% fibre) and *Raphia* peats are even more sapric. Mangrove peats do not seem to exhibit any trend in this respect. An increasing tendency towards standing water was observed from Raphia swamp, to hardwood mire, to sedge/reed mire. The wetter conditions are in the peatland, the more fibric and less sapric are the resultant peats.

These fibre categories generally represent the degree of decomposition of a peat; thus, the more fibres there are, the lower the degree of decomposition.

From this it can be reasoned that generally sedge/reed peats (which form under relatively wet conditions) are least decomposed and Raphia peats (which form under drier conditions) are most decomposed.

Hardwood swamp-forest peat is typified by white, yellow to reddish wood, leaf and wood fragments and debris. At depth wood peat is replaced sequentially by reed-/sedge-/grass-/water lily remains and finally undifferentiated organic matter and organic-rich sediment. Mangrove peats are dark brown and show dominance of roots with abundant dark debris. Thin clay and/or ash layers (with some charcoal fragments) are common. Raphia peats are reddish and generally highly humified.

TABLE 5.2 PEATLAND TYPES AND SUB-TYPES RECOGNISED IN THE NATAL MIRE COMPLEX (NMC).

- SEDGE/REED MIRE (SR)
  - Reed/sedge (Rs)
  - Sedge/reed (Sr)
  - Reed/sedge/forest (Srf)

- FOREST MIRE (FS)
  - Raphia swamp (Rs)
  - Hardwood swamp (Hw)
  - Mixed forest swamp (Mfs)
    - Rs/Hw
    - Hw/SR

- MANGROVE SWAMP (MS)
  - Pure Mangrove (Mp)
  - Mixed Mangrove (Mm)
    - Mm/Hw
    - Mm/SR

Cellular structures can still be discerned in some root fragments but most stem and leaf remains are structureless. The reason for this is that fallen trunks, leaves and petioles remain on the peat surface for a long time where they are subject to decay due to oxidation and microbial attack (Fig. 5.2C, D).

Sedge/reed peats are greenish-yellow to yellow-red with dark debris. Well-rounded quartz grains (aeolian origin) are found widely disseminated throughout most of these peats. Leaf, stem and root fragments can be recognised as well as some filamentous algae. Stems and leaves are less common than roots and are much more degraded as a result of oxidation and microbial attack in the litter layer before being incorporated into the peat.

These peats are very well stratified from the seasonal accumulation of dead plant material but also feature many plants in the living position within the accumulated peat. Minor layers of charcoal and/or ash from localised fires can occur at any depth in the peat profile. Some reed/sedge mires in the NMC have wood peat and charcoal horizons at depth indicating repeated reversions in hydroseral succession in these mires.

5.1.4.2 Maceral description.

Petrographic analyses were done in white or ultra-violet reflected light using standard polished sections and in transmitted light using thin sections (15 μ) of raw peat. The three major maceral groups (huminite, liptinite and inertinite) for each peat type are shown in pie diagrams (Fig. 5.11).

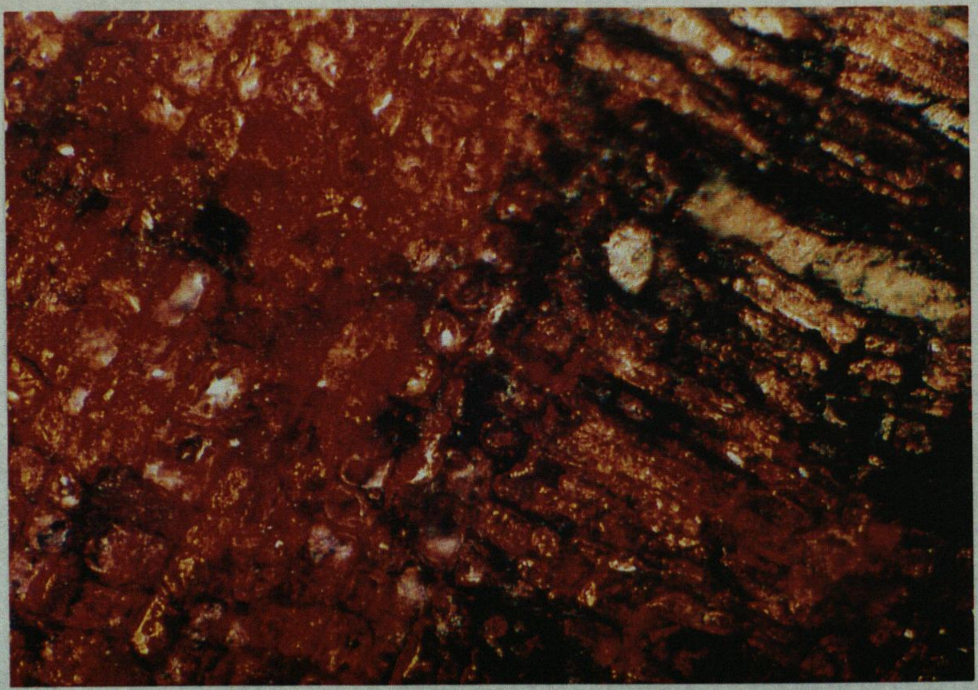
5.1.4.2.1 Huminite (Vitrinite precursor) (Fig. 5.6 and 5.7)

The huminite content (recalculated free of the organo-mineral matrix for clarity) represents 67.6% of the sedge/reed maceral composition, compared to 26.3% (Raphia peat) and 44% to 90% (forest peat). This maceral group consists of the subgroups humotelinite, humodetrinite and humocollinite. Humotellinite is the dominant maceral in Natal Mire Complex sedge/reed peats (28.3% matrix free) and forest peat (58%). In white light the tissues are red to orange (Fig. 5.6 A and B) and in ultra-violet light they are yellow-green. Humodetrinite is next most common in forest peat (19.1%) and sedge/reed peats with an average of 24.1% (Fig. 5.6 C and D).

Humocollinite (13.4% - sedge/reed, 1.6% - Raphia, 8% - forest) consists of massive, low-porosity gelified organic matter. Cell cavities in telinites are often filled with phlobaphinite (Fig. 5.6 A). Phlobaphinite develops from brown- or red-coloured cell excretions which are oxidation products of tannins which form after the death of the cell content. Phlobaphenes are found, amongst others, in medullary rays and in wood parenchyma of fallen trees (cf. Stach et al., 1982 and Van der Heijden et al., 1994).

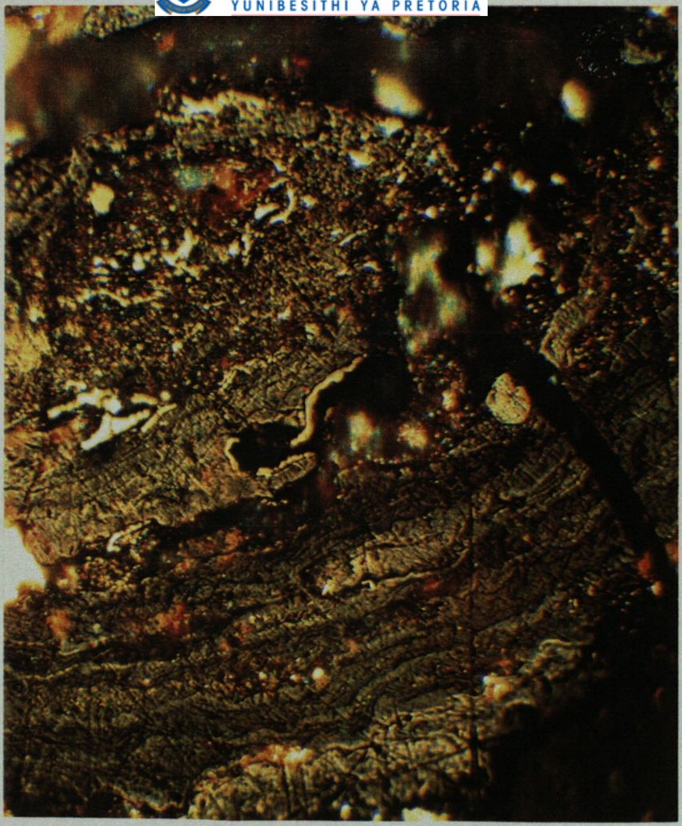
FIGURE 5.6

A). Phellem (ph) cells filled with phlobaphinite. Note granular massive detrinite towards the top of the photograph. Cross-section of part of peatified wood from Mgoboseleni. Reflected light (230 x).



B). Partial view of a radial longitudinal section of a *Syzygium* (?) stem from a forest peat. The ray cell walls are red with yellow-red fillings while the fibres have dark cell walls with yellow fillings (230 x).

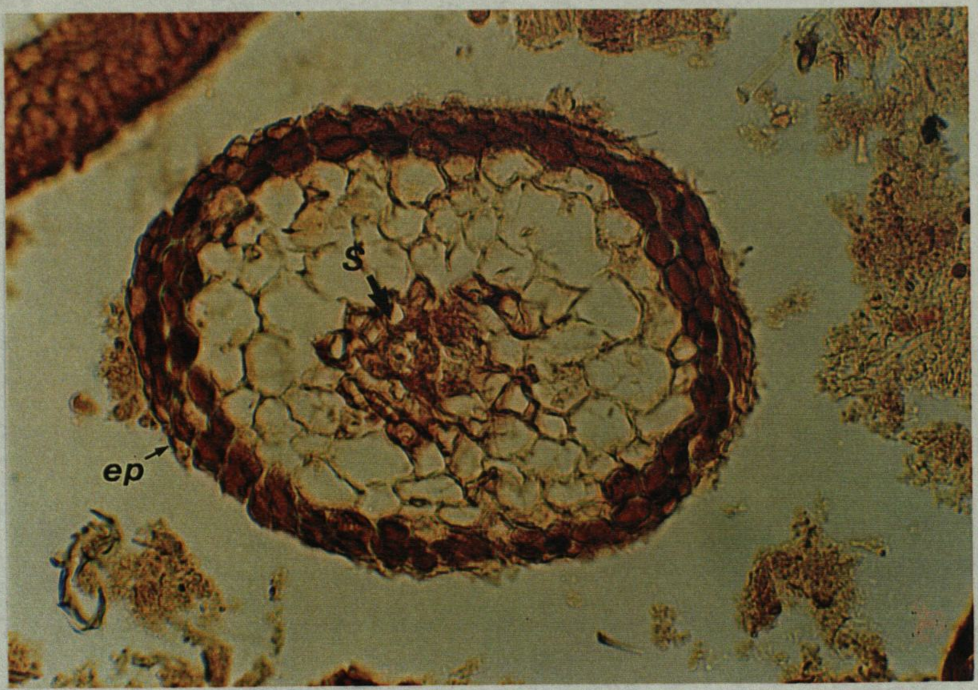
FIGURE 5.6



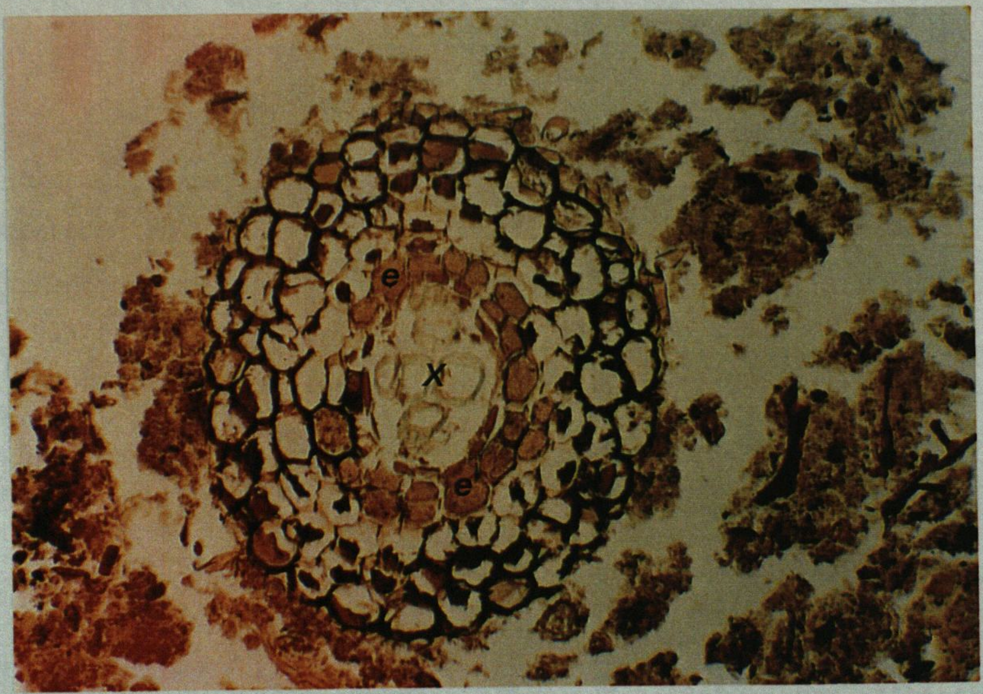
C). Humodetrinite occurs here as attrinite (detrital particles are finely divided and porous) in close association with inertodetrinite and finely disseminated mineral matter. Note also some liptinite layers present. They are gray in white reflected light but fluoresces yellow to yellow-brown (230 x).

D). Humodetrinite in close association with finely disseminated mineral matter (in places forming orange clouds). The upper banded layer (L) is a liptinite layer in the form of leaf cuticles. Here the detrinite is becoming more strongly gelified towards densinite. Sedge/reed peatfrom Lake Sibayi region (230 x).

FIGURE 5.7



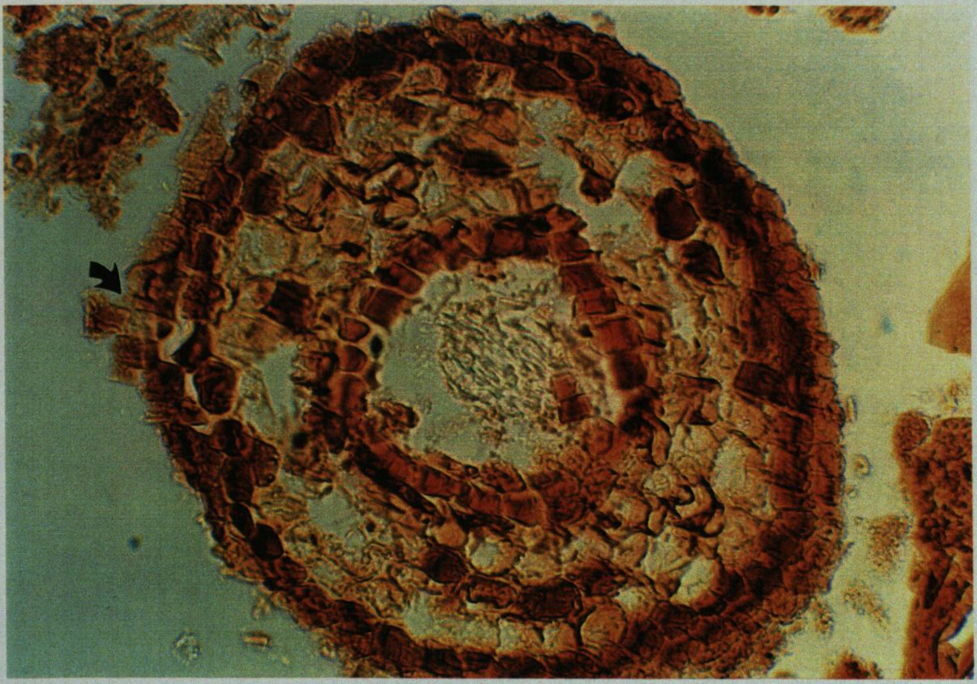
A). Cross-section of a root where the epidermis (ep) is still partly intact. The entire phellem is filled by a brown substance. The cortex is becoming fragmented and the stele is turning to an unrecognisable yellow-brown granular mass (s). Transmitted light (60 x).



B). Transverse section through a root found in sedge/reed peat. Note that the endodermis (e) cells are filled with a yellow-brown granular substance. The phloem has been totally removed and only some loosely floating primary xylem (x) remains. The epidermis has been partly destroyed and the cortex cells (thickened, with dark stained cell walls) are partially empty. Some cells have what appear to be desiccated dark-brown fillings. White light (60 x).

FIGURE 5.7

C). Transverse section of a peatified vessel from a woody stem. The secondary cell wall (arrows) is darkly stained and has collapsed. The compound middle lamella (cl) appears to be largely intact. White light (230 x).



D). The endodermal cells have been filled and subsequently the cell walls where dissolved. The xylem remains as a colourless almost amorphous mass. Some cortical cells are disintegrating while others have also been filled with a tannin-like substance, like the phellem where cell fillings are starting to "float' out of the structure (arrow) as cell walls become gelified. White light (60 x).

5.1.4.2.2 Liptinite (exinite) (Fig. 5.8)

Liptinites originate from vegetal materials such as cuticles, pollen, resins, waxes, fats and oils - all substances that occur in many of the South African peat forming plants. This is also why some huminites are green-yellow fluorescent in ultraviolet light, especially amongst younger peats where the humification process is still in its early stages.

Most common of the liptinite macerals in NMC peats are cutinite (0.4 to 4.7%) (Fig. 5.6 D) and resinite (0.2 to 8.4%) (Fig. 5.8 A and C). Sporinite contents (spores and pollen) range between 0.3% and 2%.

5.1.4.2.3 Inertinite (Fig. 5.9 and 5.10)

is the second most common maceral group making-up 29.5 % of sedge/reed, 17.5 % of raphia and 27.6 % of forest peat.

• pyrofusinite reflectivities are very high and because of the brittle nature of the fusinite sharp fragments are common. In the sedge/reed peats pyrofusinite fragments tend to be thin-walled, elongated bodies that break easily to form layers of small shard-like fragments (Fig. 5.9C) that are often redistributed as part of the inertodetrinite (Fig. 5.10A).

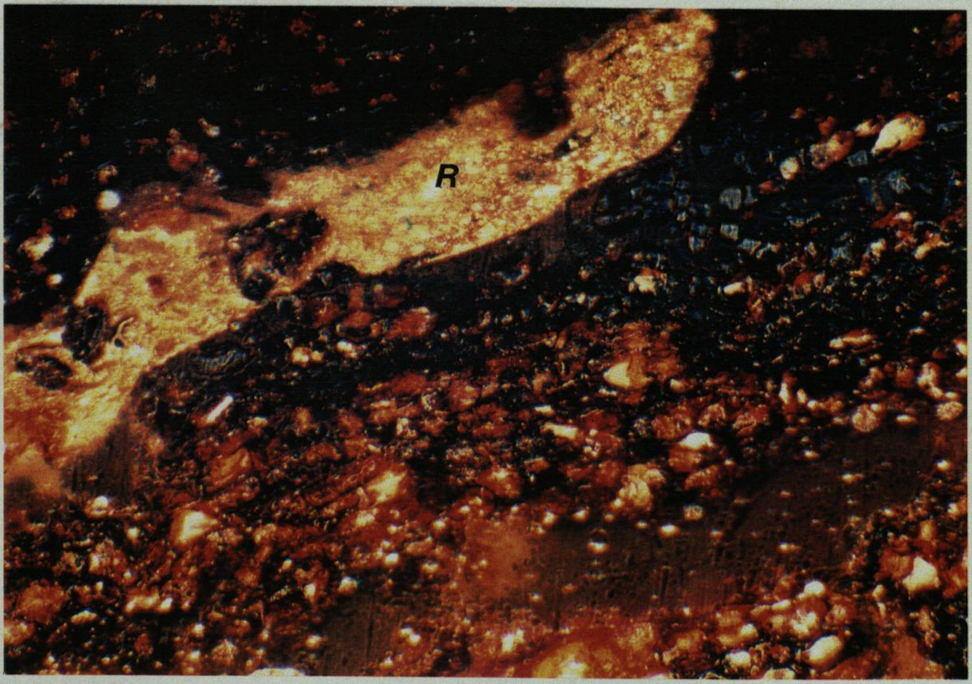
• degradofusinite (Fig. 5.9A, 5.10B) exhibits lower reflectivities than pyrofusinite.

• primary fusinite forms from a number of peat forming plants that have cell walls that are naturally dark brown to black in thin section and accordingly show relatively strong reflectivities in polished sections (Fig. 5.9D).

- sclerotinite formed from both dark fungal spores and mycelia and cell fillings or secretions (Fig. 5.8D).

The dark fungal remains were most commonly observed in sedge/reed peats.

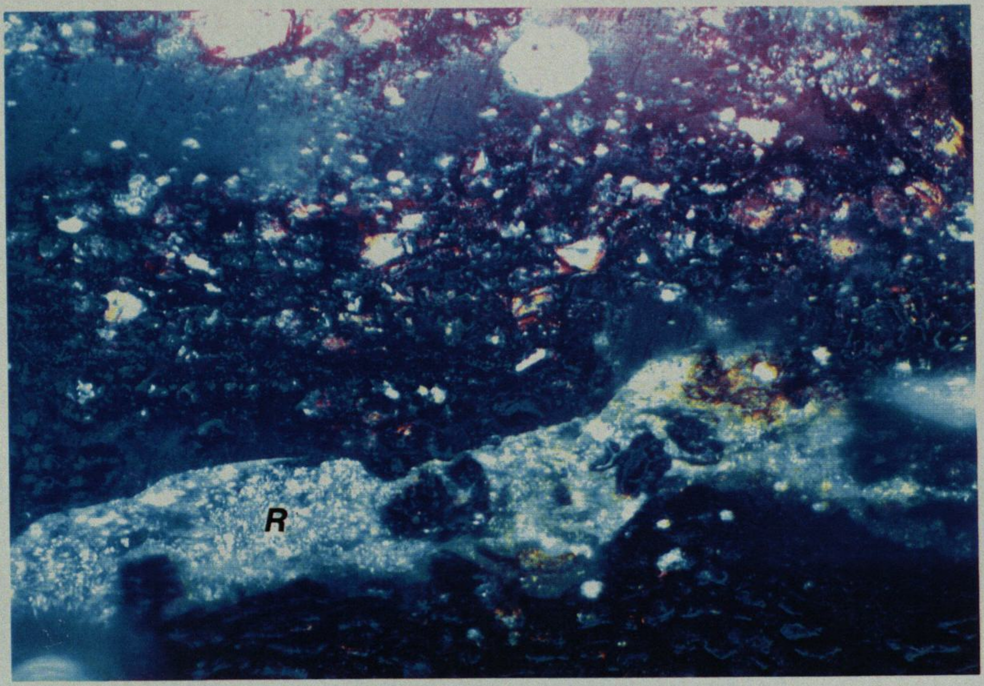
FIGURE 5.8



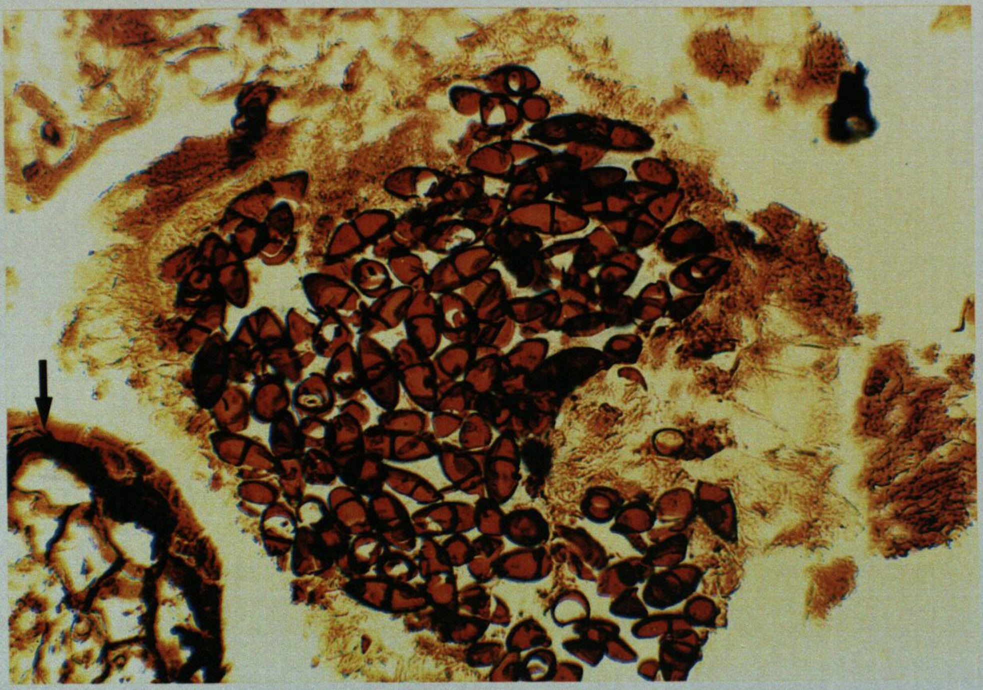
A). Part of bark layer with large resinite body (R). reflected white light (230 x).

B). Huminite with deformed and convoluted secondary cell wall remains (arrows) (cf. Cohen and Spackman, 1980, fig. 3). Note scratches on the surface of the polished section due to the softness of the peat (230 x).

FIGURE 5.8

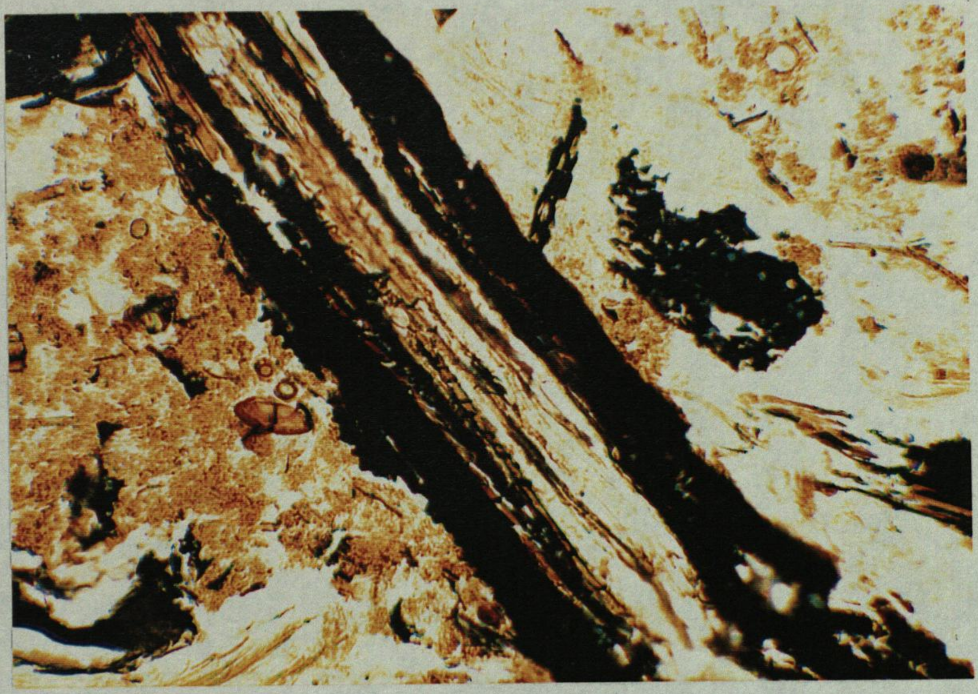


C). The resinite body in (A) fluorescing in yellow under ultraviolet irradiation.

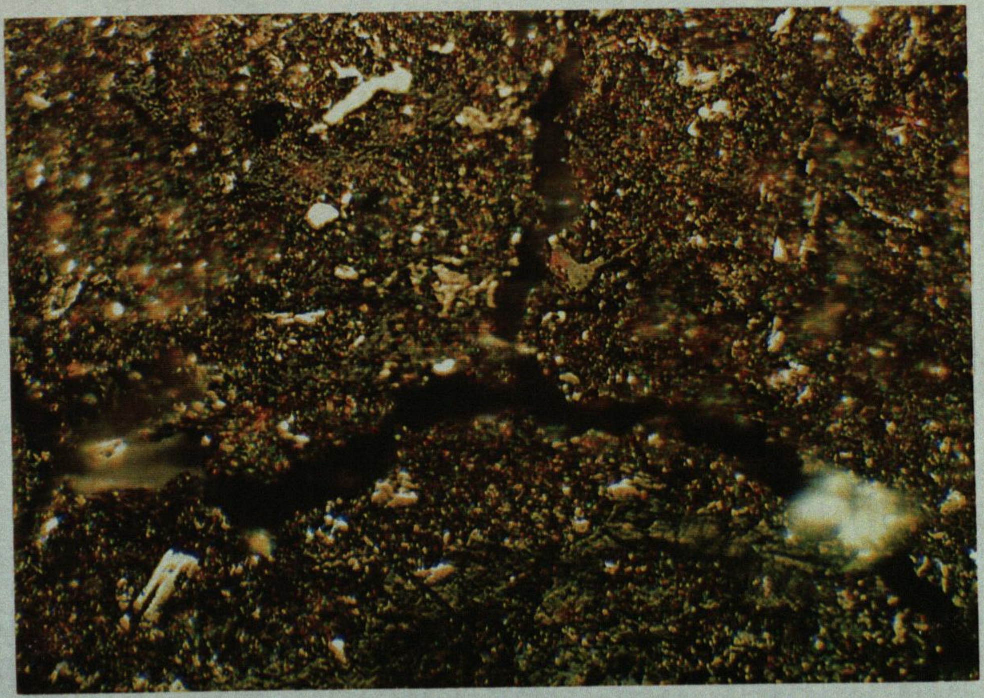


D). A cluster of fungal spores. The sporangium has been gelified but can still be seen surrounding the spores. The dark colour of the spores will lead to high reflectivities in reflected light. Such a cluster could probably be described as a sclerotinite body. Transmitted light (60 x).

FIGURE 5.9

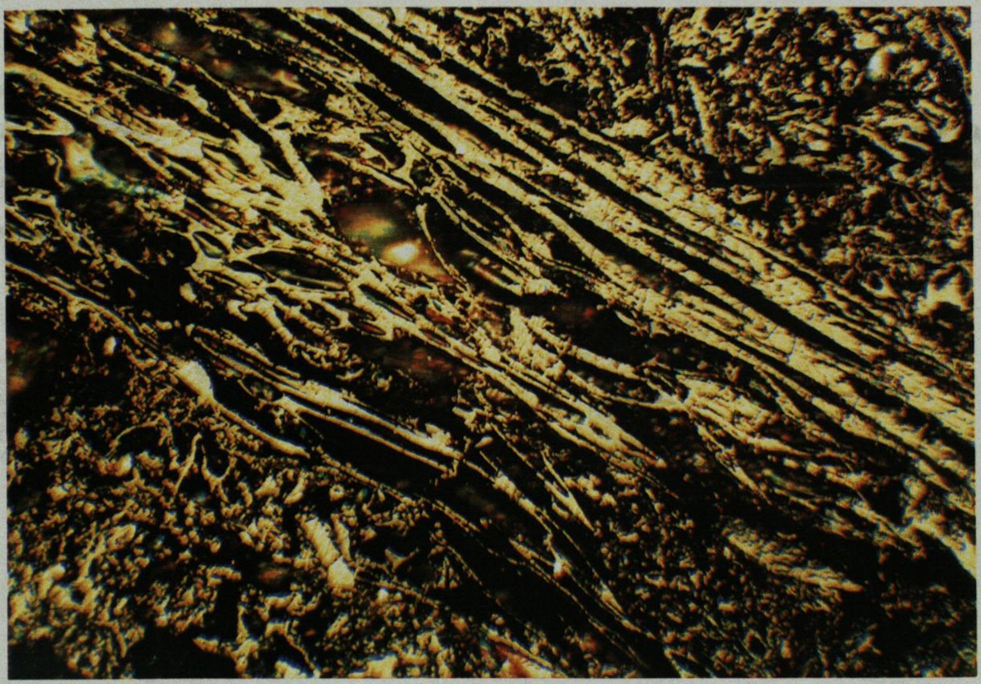


A). Thin section showing a typical pyrofusinite fragment (black) from a sedge/reed peat. The outside of this stem is totally fusinitised but the inside shows the transition from tellinite (yellow) to degradofusinite (brown) to pyrofusinite (black). Transmitted light (60 x).



B). Inertodetrinite closely associated with the organo-mineral matrix. Reflected light (230 x).

FIGURE 5.9



C). Typical sedge/reed pyrofusinite. Note elongated thin-walled fragments. Reflected light (230 x).

D). Sections through two fern-like stems that appear to be naturally dark stained (arrows), representing primary fusinite. Note also some cross- and oblique sections through water-lily rootlets (60 x).

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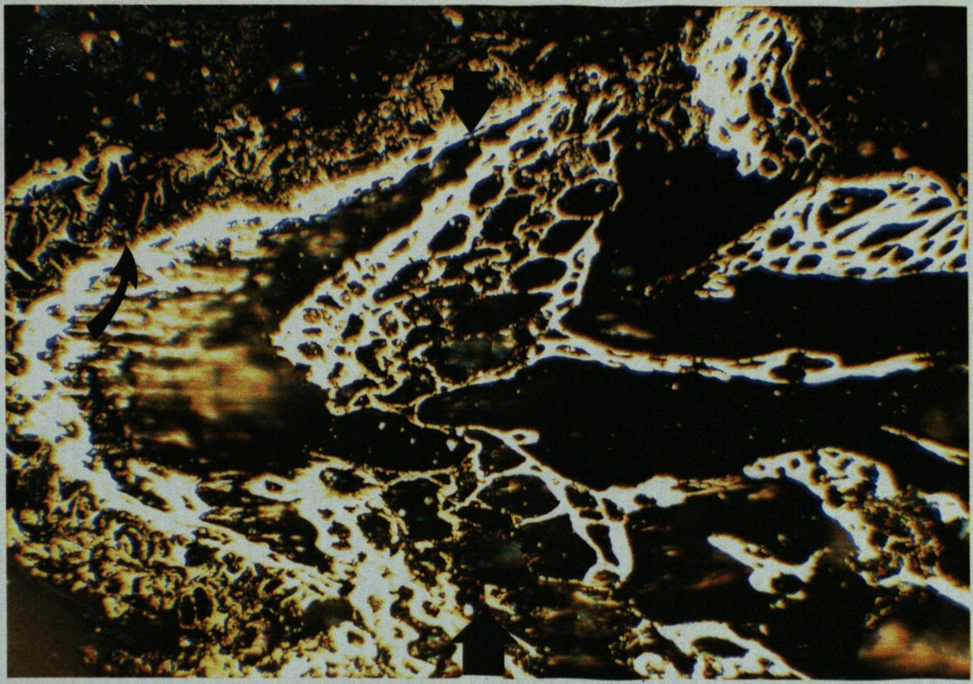
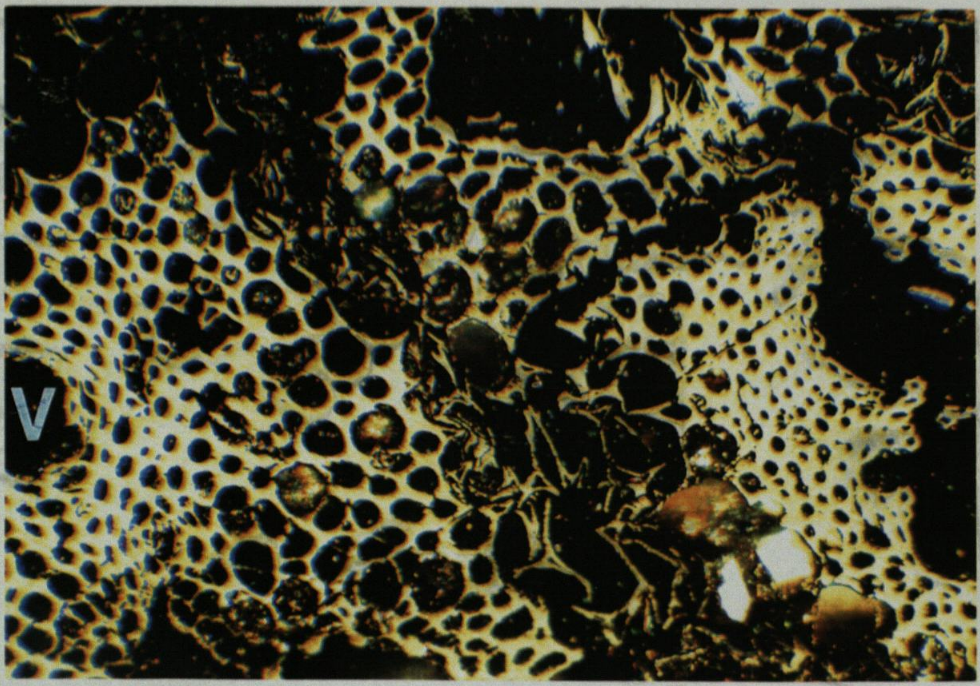
FIGURE 5.10

A). Fusinite fragments all oriented length-wise and separated into three clearly discernable layers, indicating syndepositional reworking. Reflected light (230 x).

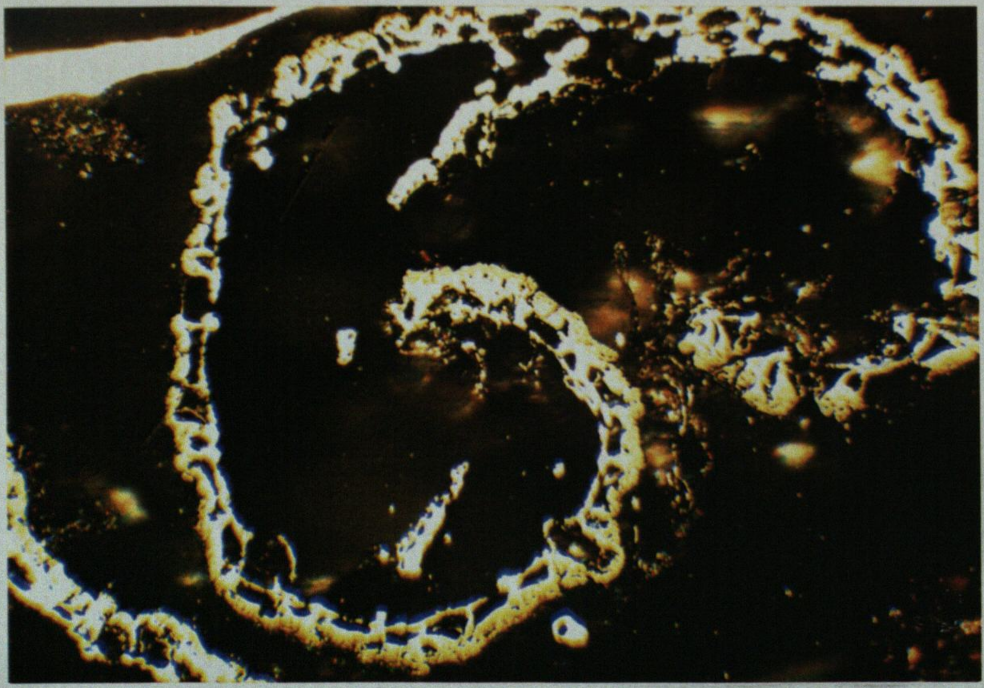


B). Note sudden change in reflectivity (arrow) of the fusinite between inside and outside of this stem. This may indicate pyrofusinite (high reflectivity) inside and degradofusinite (lower reflectivity) outside. Note the effect of compaction (big arrows) on the cell structure. Reflected light (230 x).

FIGURE 5.10

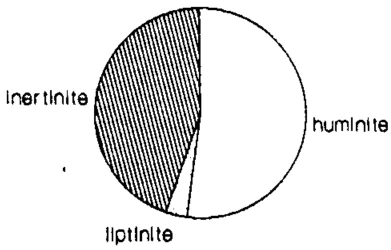


C). Cross-section through part of fusinitised hardwood stem. Note thick walled tracheids, open vessels (V) and thin walled ray parenchymatous cells that tend to break easily. Carbonised hardwoods were found to break into smaller tabular pieces along rays. Reflected light (230 x).

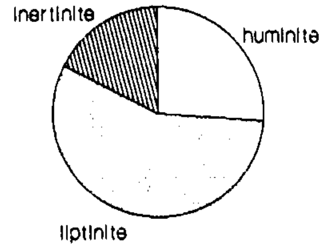


D). Cross-section through a fusinitised leaf. Sedge/reed peat. Reflected light (230 x).

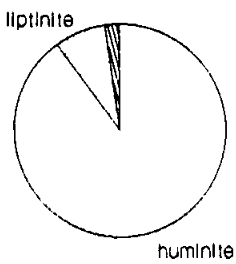
Fig. 5.11 Maceral Composition of NMC Peat Types



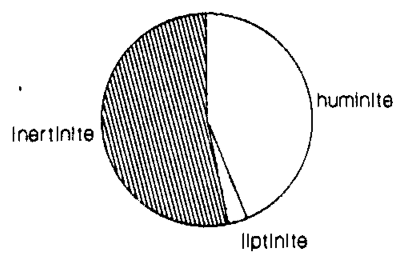
Sedge/reed



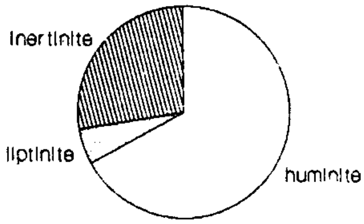
Raphia



Forest (woody component)



Forest (non-woody)



Forest (total)

Huminite = Vitrinite

Liptinite = exinite

- Inertodetrinite can often be seen transported as bedload or trapped between ripples in streams and rivers of the Natal Mire Complex. A certain amount of inertodetrinite is also washed out to sea and can be found deposited in troughs in the near-shore.

Thick "organic shadows" reported from geophysical surveys of lake bottoms in the Kosi Lake system (Andre du Plessis - Geological Survey, pers. comm. February 1993) may be large accumulations of inertodetrinite washed down the Siyadla River from the forest mires in its catchment.

5.1.4.2.4 Matrix

The matrix (which ranges in abundance from 2% to 39% in the NMC) consists of small organic particles, various clays, pyrite grains, phytoliths, sponge spicule fragments, etc.. In sedge/reed peats a large proportion of the matrix may consist of inertodetrinite.

5.1.4.3 Palynological composition.

Peat palynology on its own is an extremely complex field of study and will be used briefly to support and underscore a few points regarding the characteristics and formational history of mires. Depositional environments play a role in pollen preservation and Stach et al. (1982) indicate a number of examples where marine influences led to a paucity of spores and pollen in peats and coals.

Similar indications of a dramatic reduction in the pollen count have been observed in a NMC forest mire in association with clay horizons believed to be indicative of marine incursions (Fig. 5.12; fig. 5.15C shows the setting of the sample). Note how the pollen count (total number of grains liberated from a standard sample of peat using international standard techniques) is always at a minimum just below the inferred marine clay horizon. The marine influence results in an increase in pH, leading to enhanced bacterial activity resulting in a drop in pollen content. The pollen being deposited may also be reduced by being reworked in the winnowing action of the tides. The paucity of pollen may also be ascribed to a number of other reasons, e.g. brackish and marine plants may produce less pollen, organic sediment is diluted with the increased inorganic contribution, hydraulic equivalency of particles, etc.. Spores and pollen have also been found largely absent from certain peat horizons in sedge/reed mires known to have had a strong water flow at times. This phenomenon may be the result of pollen being flushed from more fibrous peat horizons during these relatively higher energy episodes in the mire.

It is possible to determine the hydroseral succession for a particular mire using palynology and petrography to corroborate each other. Mazus (1992) has indicated how open water aquatic assemblages are successively replaced by gramineae, followed by swamp forest elements (Fig. 5.13). The left-hand column in Figure 5.13 (a typical pollen diagram) refers to the ratio of non-tree (NAP) to tree pollen (AP). The depth of the peat profile is given in centimetres down the left of the NAP/AP column and percentage of pollen counted at the bottom of each column.

Sodwana Bay DA1 is a core from a reed/sedge mire immediately behind the high coastal dune cordon. The mire stretches from the outflow of Lake Mgobozeleni, downstream towards the sea, merging into a mangrove swamp before the Mgobozeleni stream enters the Indian Ocean (Fig. 5.15C) (Smuts, 1992). Sodwana Bay DA2 is an interdune swamp forest mire located on the southern bank of Lake Mgobozeleni (Fig. 5.15C). The edges of mire DA1 are now being encroached upon by an increasing number of woody species such as *Ficus* spp., *Myrica* and *Hibiscus tiliaceus*, while the woody community on DA2 is already well established (cf. Fig. 5.3C).

DA2 is believed to have been a shallower extension of the lake that was filled in with peat during the process of terrestrialization. The indication of open water earlier in the history of the mire is given by *Nymphaea* (water lily) and *Typha* (bull rush) pollen that occurs in the lower part of the peat profile, disappearing as the open waters were filled in (compare to DA1 where *Typha* is increasing upwards throughout the profile). *Nymphaea* however, is absent here as the water was never deep or open enough. Note also the relative abundance of Myrtaceae pollen in DA2. Pollen of the water berry tree (*Syzygium cordatum*) is common in DA2 whilst it is virtually absent in DA1. *Myrica serrata* is common in NMC swamp forests and damp places, appearing early in the hydroseral succession from fen to fen carr along with *Syzygium*. This would explain the presence of both genera throughout profile DA2.

5.1.5 Physical-chemical properties of the peat

5.1.5.1 Proximate analysis.

Proximate analyses (moisture, fixed carbon, volatile matter and ash content) and calorific value determinations were done on both peat and organic-rich sediment samples (ash content >50%). However, for certain analytical calculations and discussions that follow, only peat samples were considered (Table 5.3).

TABLE 5.3 CHARACTERISTICS OF ALL NMC PEATS (ASH < 50%) IRRESPECTIVE OF TYPE (moisture-free basis)

	average (%)	range (%)
Fixed Carbon	25	10 - 29
Volatile Matter	48	35 - 68
ash	27	1 - 47
Calorific Value (MJ/kg)	16.5	11 - 22

5.1.5.1.1 Ash contents

Ash contents of mangrove peats are significantly higher than those of any other peats (Fig. 5.14). This is probably because these peats formed at the edges of brackish river channels or in the lower reaches of estuaries (Fig. 4.1, 4.2). All freshwater peats have very similar ash contents with swamp forest peats exhibiting the lowest average value. Two likely reasons for this are that the vegetation that produces swamp-forest peat contains less authigenic silica (intracellular phytoliths) than other types of peat-forming plants (notably grasses and sedges) and swamp-forest peatlands are better protected against the incursion of mineral material in the form of water- or wind-carried sediments.

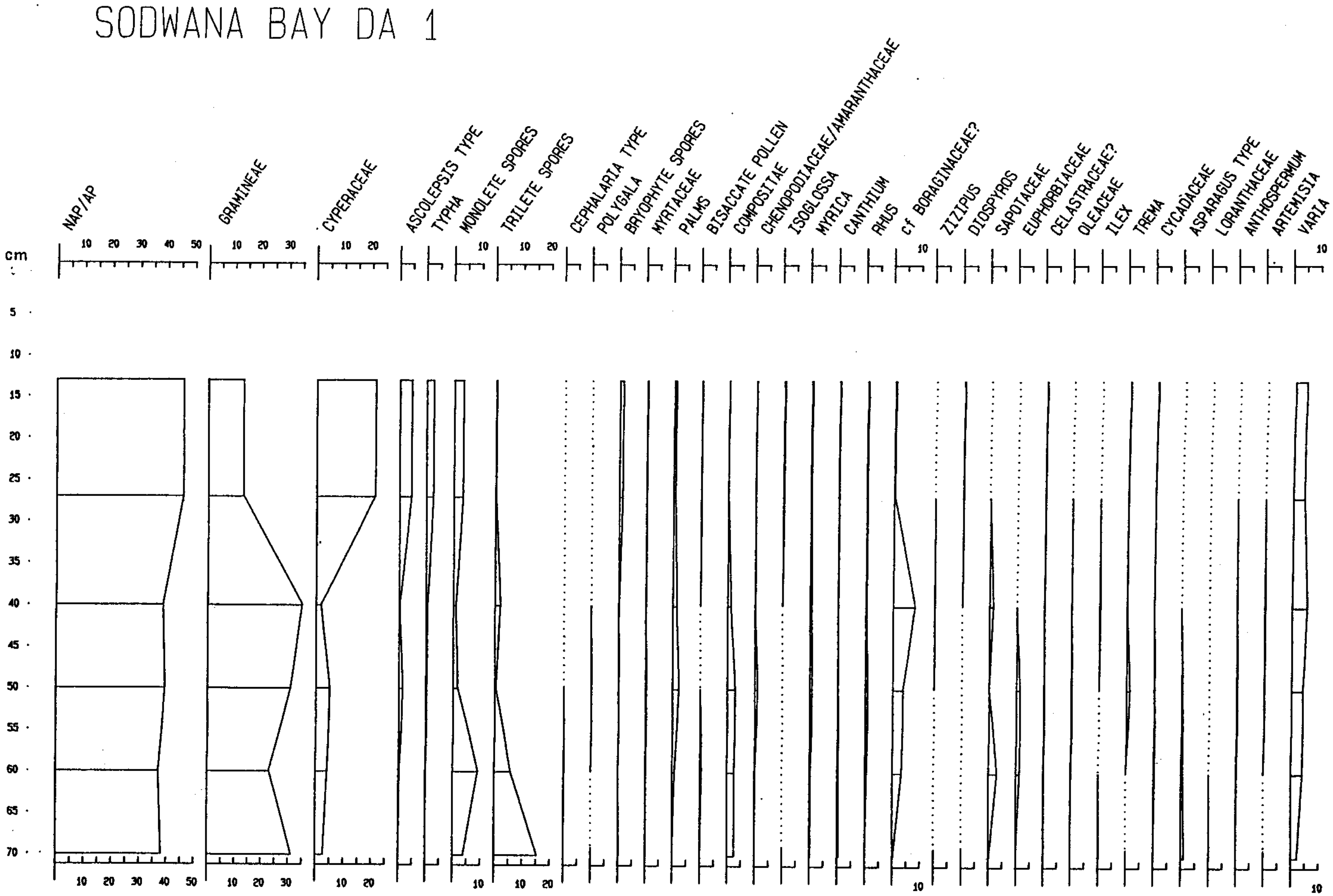


Fig. 5.13 Pollen diagram for Mgobozeleni (Fig. 5.15C) (after Mazus 1992)

SODWANA BAY DA2

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

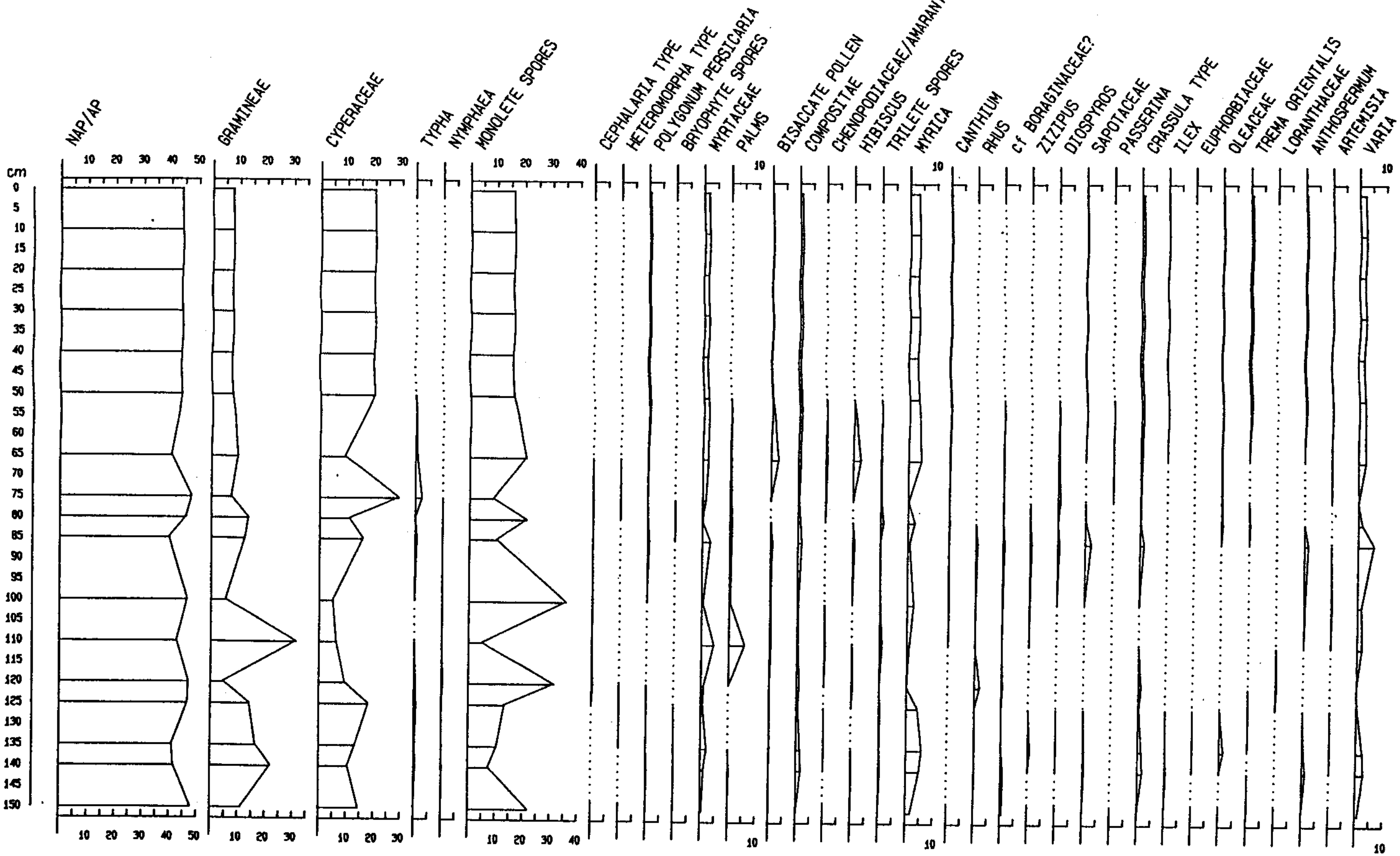


Fig. 5.14 Ash (wt%, air dry) distributions for the major NMC peat types

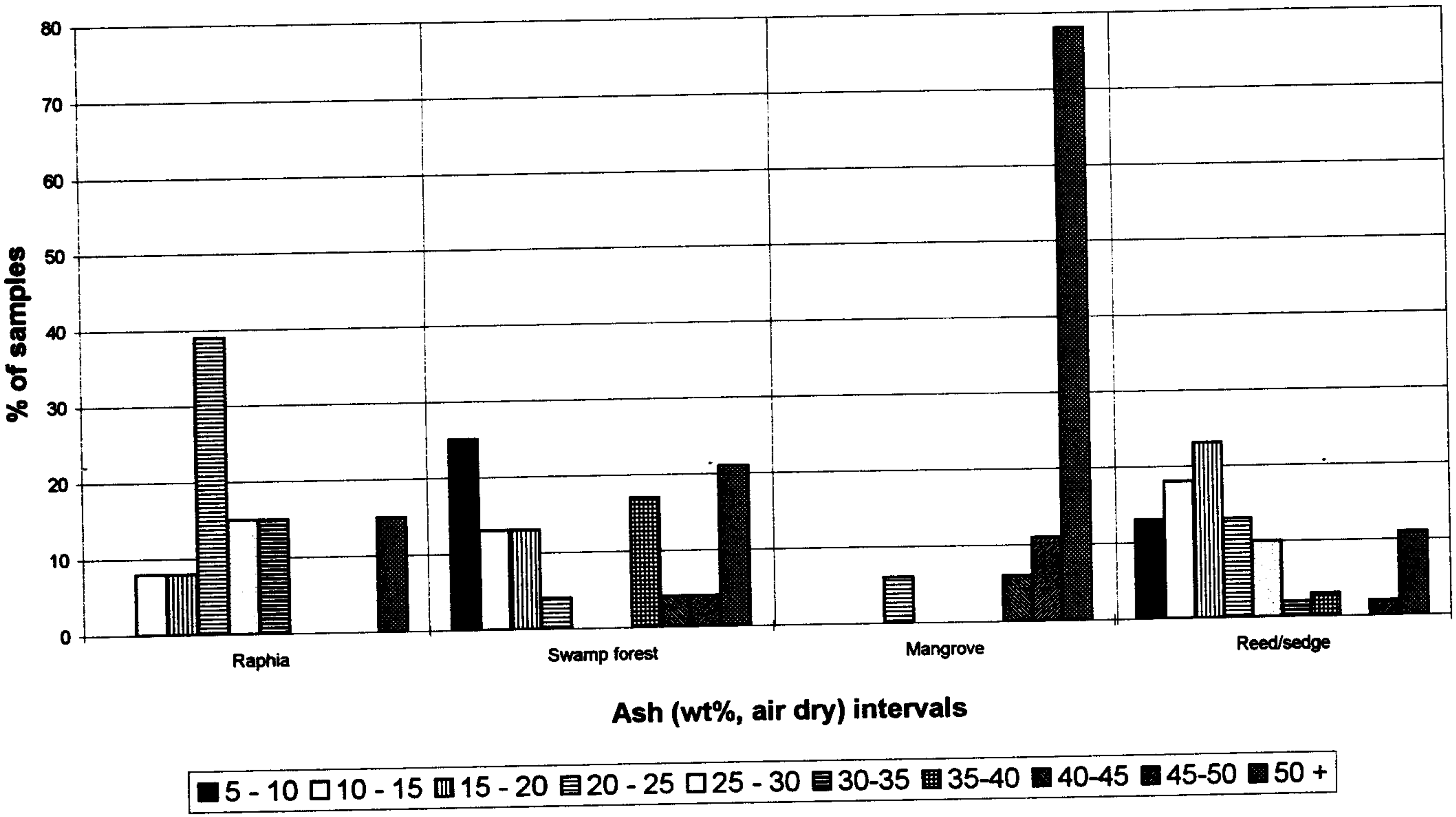


Figure 5.15 shows the ash content of cores taken across a forest mire (see Fig. 5.5 for the relative position of each core in the peatland) and a sedge/reed mire. Cores 2/2 and 2/8 were proximal to the edges whereas 2/6 and 2/7 were from the central part of the peatland. There was a general decrease in ash content from shallow to deeper peats in the central part of the peatland further away from possible inorganic influx (Figs 5.5, 5.15A). Thin proximal peats (shallow dipping bottom topography)(2/2) also exhibit much higher ash contents than thick (2/8) proximal peats (steep bottom topography).

There appear to be two reasons for this, namely: thick proximal peats are influenced to a much lesser extent by the mineral base, and steep edges to a peatland tend to be associated with smaller run-off areas, thus feeding less mineral material into the peatland. The western edge of this peatland is flanked by a high dune which acted as the main source of sediment input into the interdune area. This resulted in thin, high-ash peats along the western edge. The two ash peaks in core 2/6 are exactly the same distance apart as the two ash peaks in core 2/7, indicating that these peaks may be synchronous. The fact that the peaks in 2/6 are 15 cm lower can be explained by an undulating peat surface, uneven underlying substrate or slumping within the peat between the two positions.

In core 2/6" (same distance as 2/6 from the edge of the mire but ± 100m away from the lake edge) the lower ash peak is still evident but less pronounced and the average ash contents are lower than that of the peats proximal to the lake (Fig. 5.15A). Core 2/7" only indicates a constant increase in ash content with depth. From these profiles any of the following can also be suggested; 1). there are horizons within the peat where the non-organic fraction has been leached out chemically, resulting in very low ash values, 2). these very low ash values represent very low energy situations, or much of the inorganic fraction have been washed out of more fibre-rich horizons during periods of higher flow rates through the peat (increment 70 - 80cm, cores DA 2/6" and 2/7") (Fig. 5.15A).

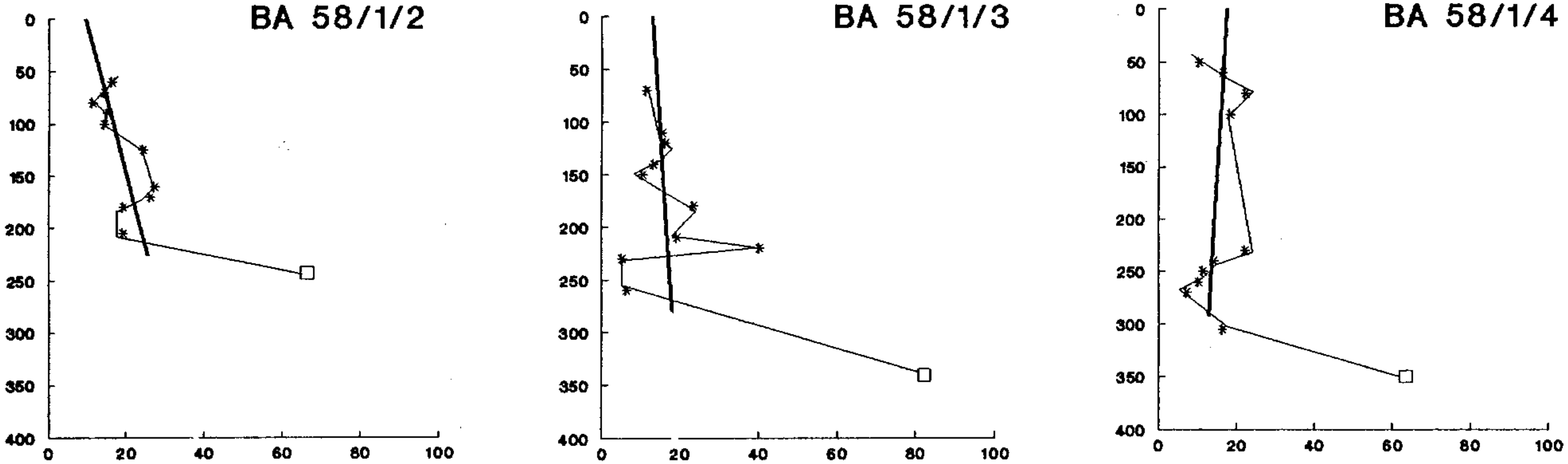
In the case of sedge/reed peatlands an increase in mean ash content with depth is observed in thinner peats near the edge of the deposit (core BA 58/1/2 and 58/4/3, Fig. 5.15B). The peats further away from the edge (cores BA 58/1/4, 58/3/2) exhibit a decreasing tendency in ash with depth. Note also that in all cores there is a definite low-ash zone in the lower 50cm to 100cm peat just above the basal clay layer (Fig. 5.15B) (each sample point on a transect is approximately 25m apart and the distance between transects BA 58/1 and BA 58/4 is about 500m). This trend can be observed in all sedge/reed mires.

The general zigzag nature of ash contents in sedge/reed mires (Fig. 5.15B) can be ascribed to oscillating climatic conditions. For example, during dry periods ash may be increased by the prevalence of fires and/or biological decay, larger volumes of dust being blown into the mires and more sediment being washed in from barren high ground during flash floods. Conversely, during wetter periods fires will be less frequent and less widespread, dust will be largely absent and less erosion will occur from the surrounding high ground. At the same time the rate of primary production in the mire will also be higher and larger volumes of peat will accumulate. Channel switching (particularly in a valley mire) may also cause similar ash content variations in the peat profile.

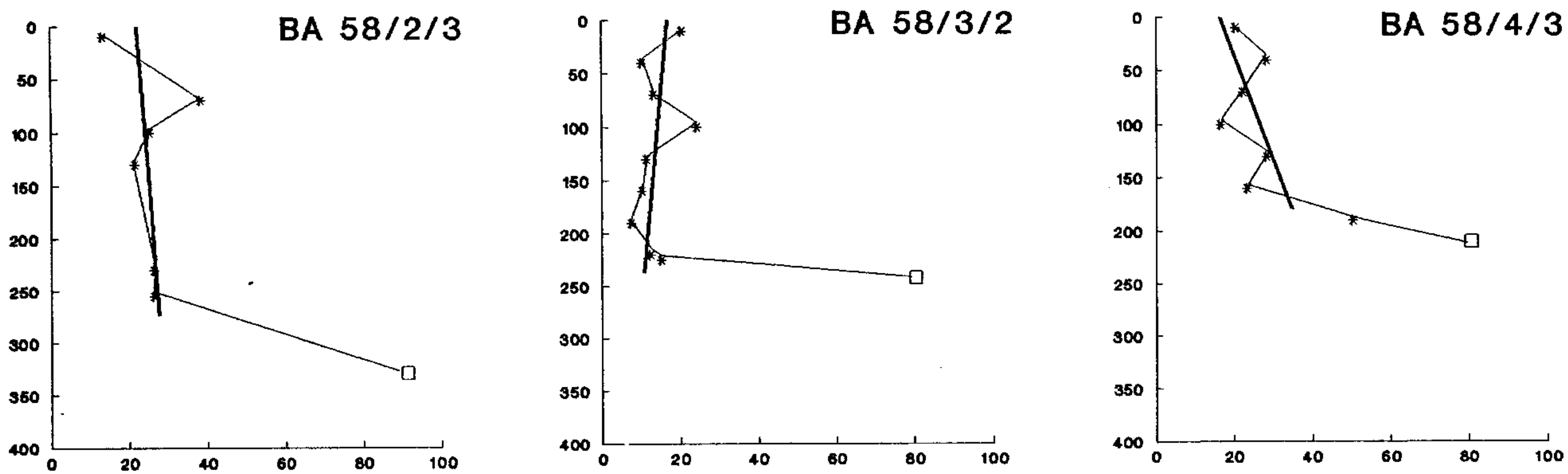
5.1.5.1.2 Fixed carbon and Volatile matter.

In Figure 5.16 a weak positive correlation is observed between fixed carbon (daf) and depth in the case of Raphia palm peat. In the case of swamp forest, reed/sedge, and mangrove peat no correlation between fixed carbon and depth was observed. These observations differ from the findings of Cohen et al. (1990) on the peats of Panama where a tendency was observed for fixed carbon and calorific values to increase with depth, especially if plotted for single peat types. Wide ranges in fixed carbon were observed between different peat types (Fig. 5.17).

Fig. 5.15 B Ash/depth profiles from a NMC sedge/reed mire



profiles 1/2, 1/3 and 1/4 were taken across the mire from the edge to the middle



profiles 2/3, 1/3, 3/2 and 4/3 represent a south to north thalweg line

Fig. 5.15 A Ash/depth profiles from a forest mire associated with Lake Mgobozeleni

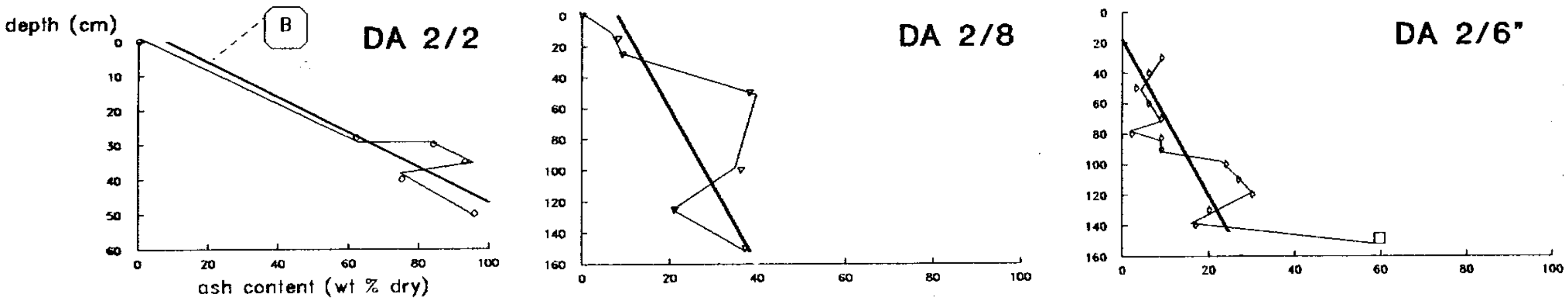
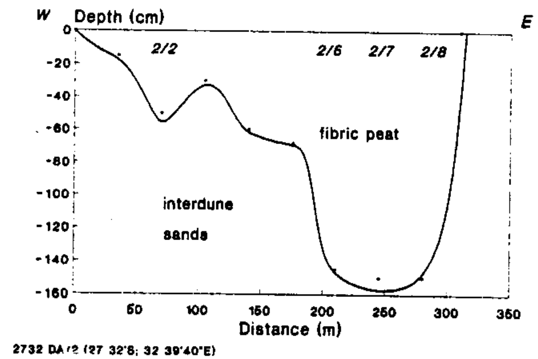


Fig. 5.5 Cross section through a Swamp Forest mire (Mgobozeleni)



B = ash trend with depth

Profiles 2/2, 2/6, 2/7 and 2/8 were located 5m from the edge of lake Mgobozeleni (see Fig. 5.5 for cross-section and 5.15 C for locality)

Profile 2/6" and 2/7" were located 100m from the lake edge

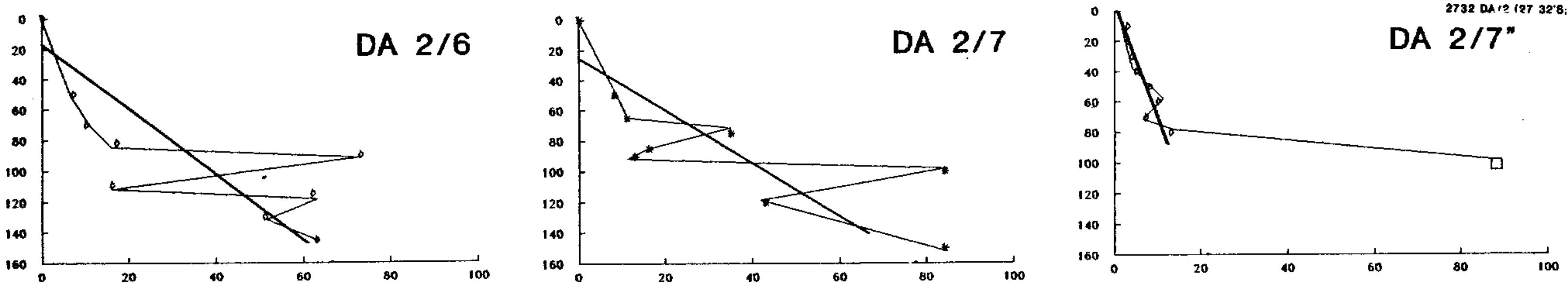
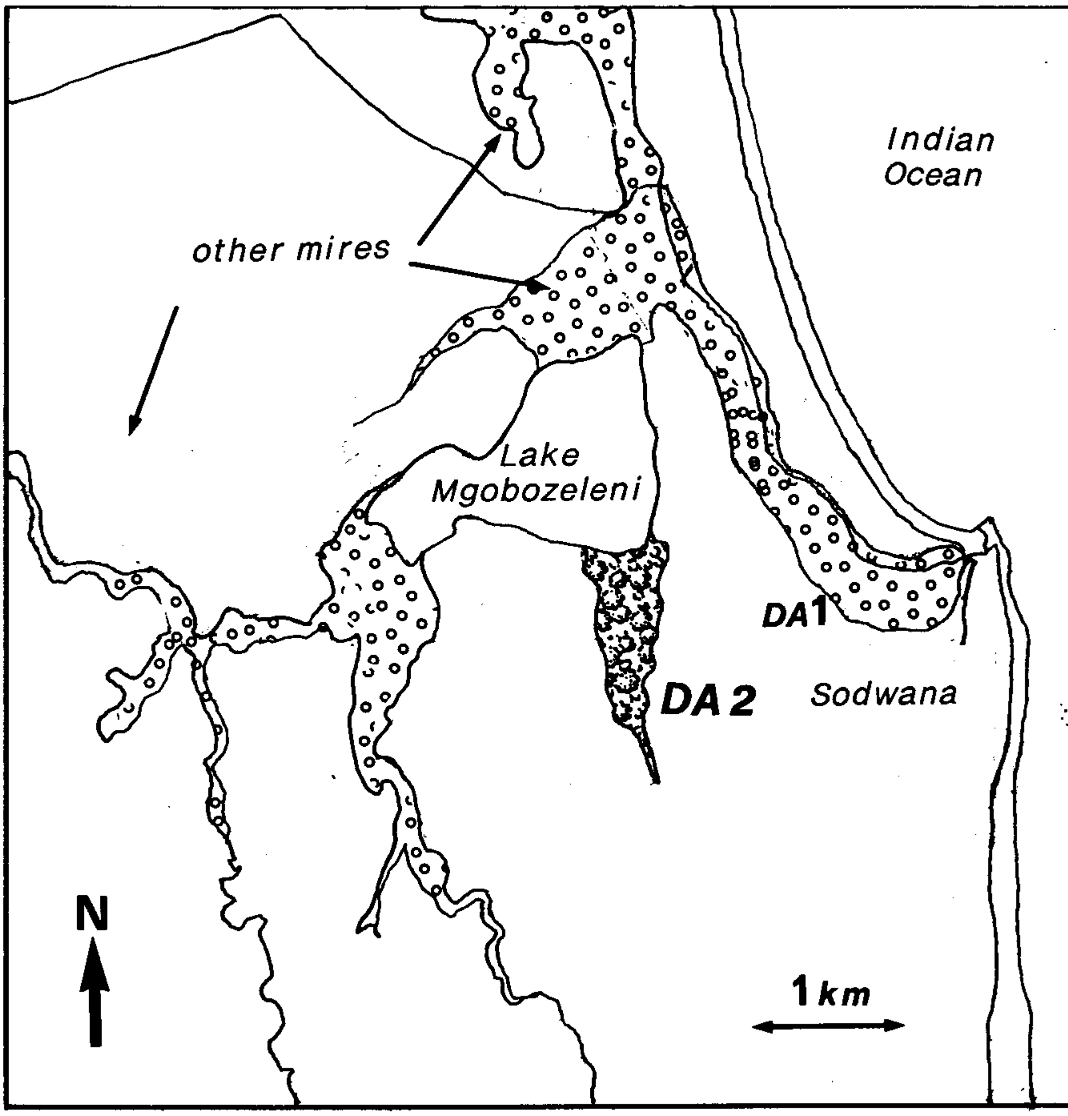


Fig. 5.15 C Locality maps for forest mire DA2 (Mgobozeleni, 27°32'S; 32°39'40"E) and sedge/reed mire BA58 (Mvelabusha alias Drie Boompies, 27°08'S; 32°40'E).



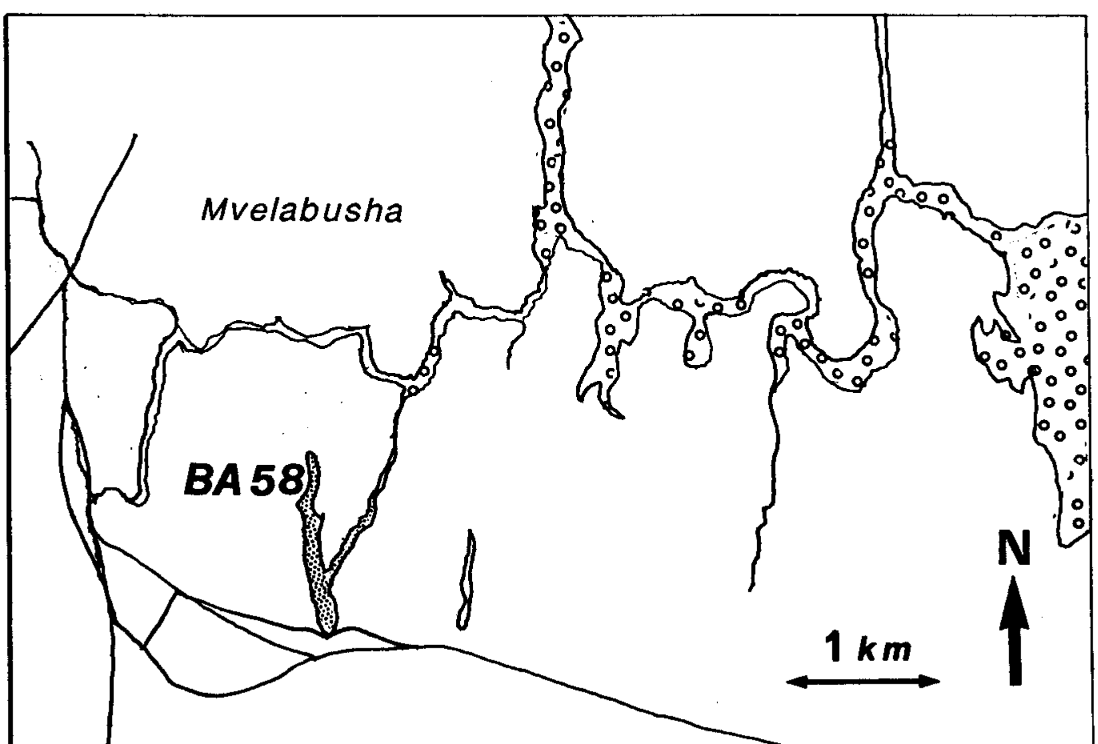


FIG. 5.16 Fixed Carbon (% daf) versus depth for the four dominant NMC peat types

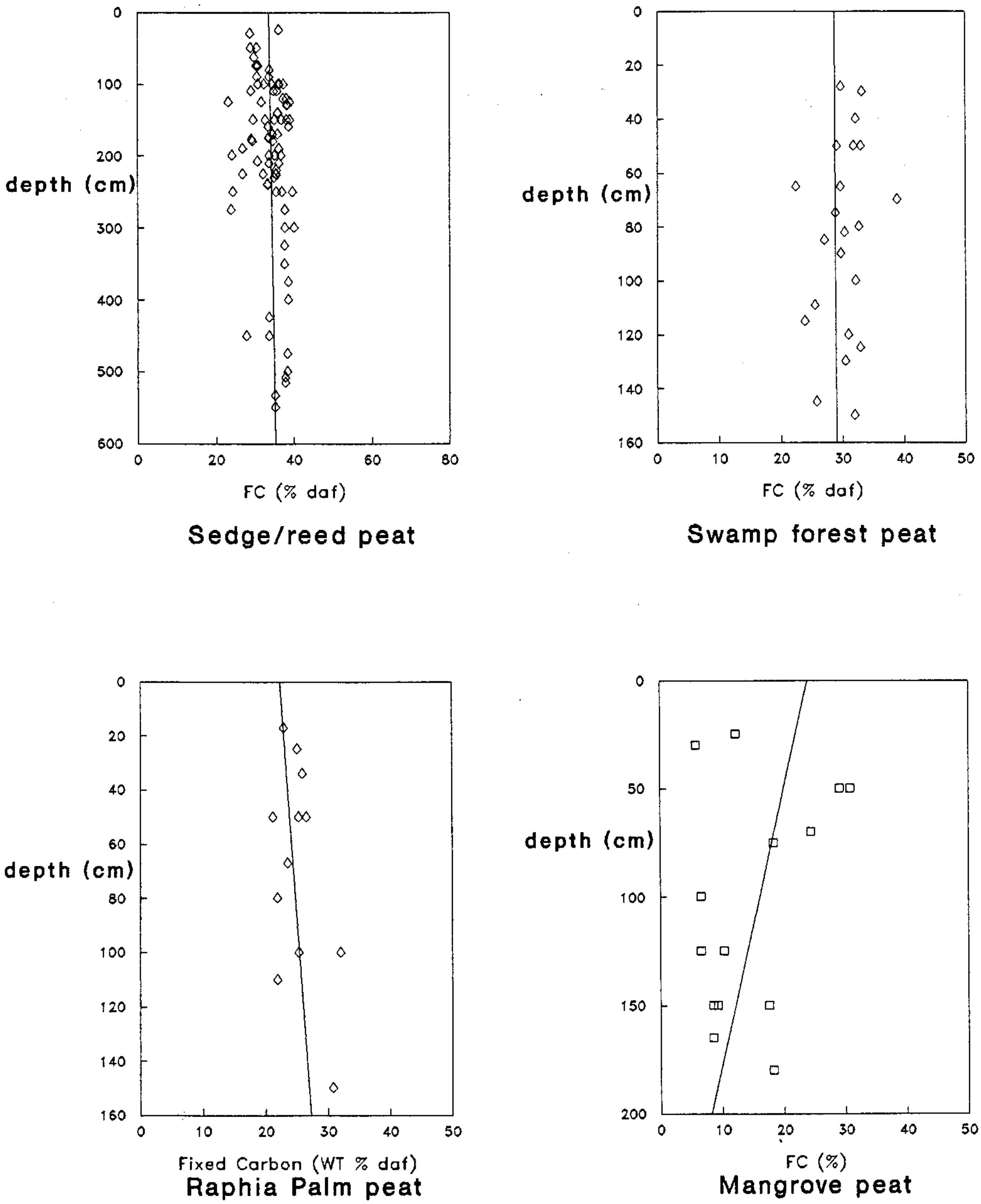
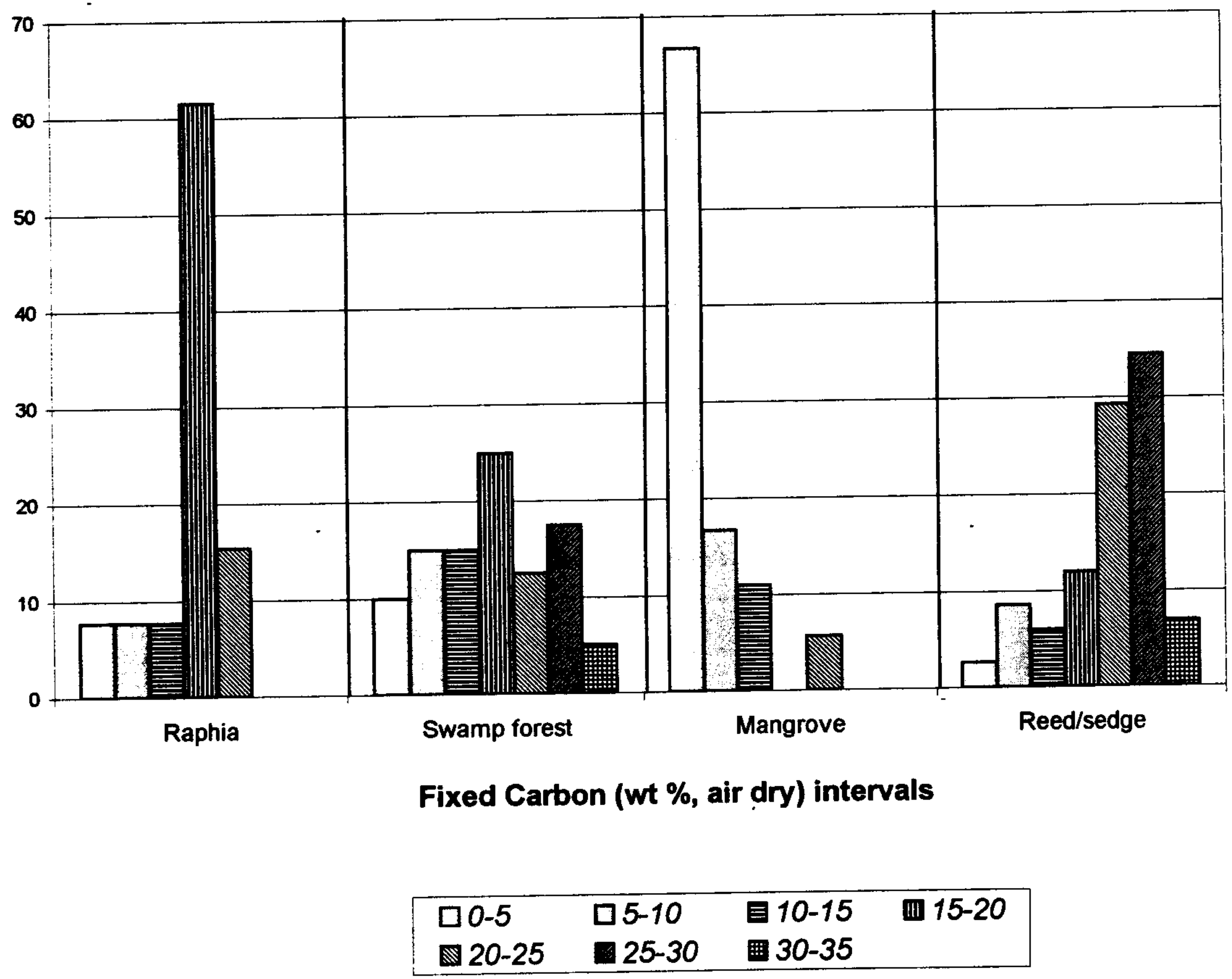


Fig. 5.17 Fixed Carbon (% air dry) for the dominant NMC peat types



5.1.5.2 Elemental analyses (Table 5.4).

Ten peat samples from the Natal Mire Complex were submitted for elemental or ultimate analysis. One of these analyses (2732 DA 2/7 at 120 cm) is totally unacceptable as the calorific value calculated from the elemental composition is about 70% higher than the determined value. The latter, however, is in close agreement with the value calculated from the volatile matter and fixed carbon contents (Appendix 3). The principal elemental characteristics of the remaining nine samples are summarised in Table 5.4.

TABLE 5.4 Elemental characteristics of NMC peat samples (daf)

	mass basis						atomic ratio	
SAMPLE	% C	% H	% O	O/C	H/C	% decomposition	O/C	H/C
Black Rock 2732BB20/3/50cm	53.64	5.80	37.48	0.70	0.108	18	0.52	1.30
220cm	62.34	5.43	30.72	0.49	0.087	42	0.37	1.04
240 cm	60.58	5.05	32.08	0.53	0.083	38	0.40	1.00
Mgobozeleni 2732DA2/2/43 cm (peat wood)	49.40	5.07	43.35	0.88	0.103	-4	0.66	1.23
2732DA2/7/0 cm (peat wood)	48.76	5.67	44.26	0.91	0.116	-7	0.68	1.40
94 cm (peat wood)	53.88	5.83	37.95	0.70	0.108	18	0.53	1.30
2732DA2/8/22 cm (peat wood)	50.24	5.15	42.86	0.85	0.103	0	0.64	1.23
145 cm	56.94	5.20	35.64	0.63	0.091	26	0.47	1.10
Sibayi 2732BC13/150 cm (peat wood)	57.82	5.71	33.27	0.58	0.099	32	0.43	1.19

The O/C and H/C ratios decrease exponentially with depth (Fig. 5.18), apparently according to the following equations:

O/C = 0.91 exp. - 0.002475 D .... (1)

and H/C = 0.116 exp. - 0.001352 D .... (2)

where D is the depth in centimetres.

The initial O/C ratio of 0.91 at the surface falls well within the range given by Van Krevelen (1961, p124) for cellulose, lignin and wood, viz. 1.11, 0.48 and 0.87 respectively. The percentage decomposition (Table 5.4) was calculated by assuming the initial O/C ratio given by Davydik (1987) who defined the decomposition (D') as follows:

$$D' = \frac{do - d}{do},$$

where do = initial O/C ratio (0.85)

d = O/C ratio of the peat.

The samples with atomic O/C and H/C ratios of more than 0.4 and 1.2 respectively fall between lignin and wood (i.e. lignin plus cellulose) on the biochemical coalification diagram of Van Krevelen (1961, p116), whereas the others agree with the band of vitrinite and inertinite genesis.

Equations (1) and (2) present the possibility to adjust analysis 2732DA 2/7 at 120cm (Appendix 3) to agree reasonably well with the determined calorific value (22.5 MJ/kg, daf). According to the depth of 120cm O/C and H/C should be 0.676 and 0.0986 respectively. Based on an initial assumption that the percentages of hydrogen, nitrogen and sulphur are correct the combined carbon and oxygen should be 100 - 7.71 - 3.80 - 0.15 = 88.34%

Therefore: $\frac{\%O}{\%O+\%C} = \frac{0.639}{1.639} = \frac{\%O}{88.34\%}$ $\therefore$ %O = 34.44

and %C = 88.34 - 34.44

= 53.90.

Based on 53.90% carbon the hydrogen content is adjusted ; ie. %H/%C = 0.0972

$\therefore$ % H = 53.90 * 0.0972

= 5.24

By reiteration the new percentage of combined carbon and oxygen is;

100 - 5.24 - 3.80 - 0.15 = 90.81% and the calculation is repeated. The results are summarised below:

TABLE 5.5 RECALCULATED CV (MJ/kg)

	%C	%H	%O	%N	%S	CV(calculated)
Original analysis (daf)	87.56	7.71	0.78	3.80	0.15	38.893
First adjustment	52.71	5.20	35.63	3.80	0.15	20.259
Second adjustment	54.21	5.35	36.64	3.80	0.15	20.832
Third adjustment	54.12	5.34	36.58	3.80	0.15	20.796

No significant changes are evident after the second reiteration.

5.1.5.3 Calorific Value

In view of the decrease in O/C and H/C ratios with depth it can be expected that the calorific value (daf) will tend to increase with increasing depth. This is indeed found to be the case (Fig. 5.19).

A value of about 17MJ/kg (moist, ash free) is considered by Stach et al. (1982) to be the boundary between soft and hard brown coal. Assuming a bed moisture content of about 35% (ash free) this would correspond to about 25.75 MJ/kg (daf). The calorific value of peat is generally considered to be even lower. The highest calorific value (daf) of peats from the NMC is about 26 MJ/kg, which would place them in the same rank as brown coals. However the total carbon content and volatile matter content of the present samples agree with those of peat (Stach et al. 1982, p42). Van Krevelen (1961, p.124)* gives elemental compositions of peat and peat precursors which would correspond with the following calorific values:

cellulose	17.2 MJ/kg (daf)
lignin	24.7
wood	19.8
peat	19.9

Fig. 5.18 O/C and H/C ratios (weight percent) versus depth

O/C = (–· —) H/C = (——)

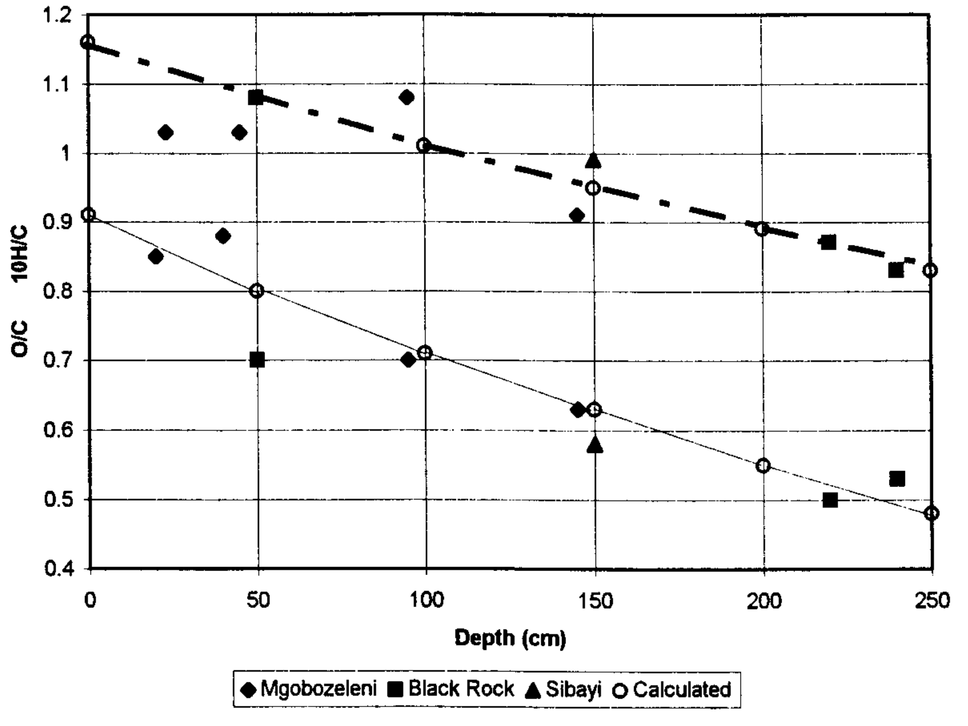
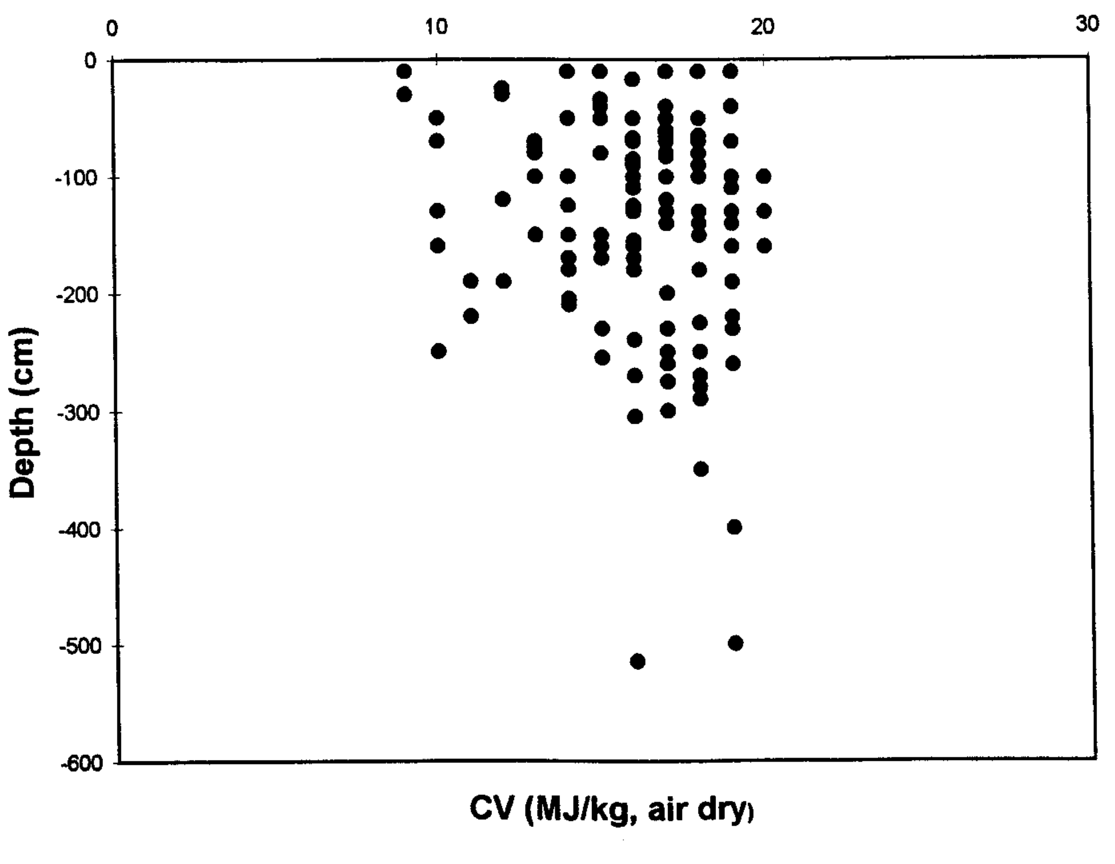


Fig. 5.19 Calorific value versus depth for NMC peats



Cameron et al. (1989), however, give elemental compositions for peats from various cold temperate to tropical environments which would correspond to the following calorific values:

Sumatra	23.5 - 27.7 MJ/kg (daf)
North Carolina	25.2
South Carolina	23.9
Minnesota	22.7
Maine	21.1 - 25.7

All these values are in keeping with those listed in Appendix 2, so that the rank parameters given by Stach et al. (1982) are ambiguous.

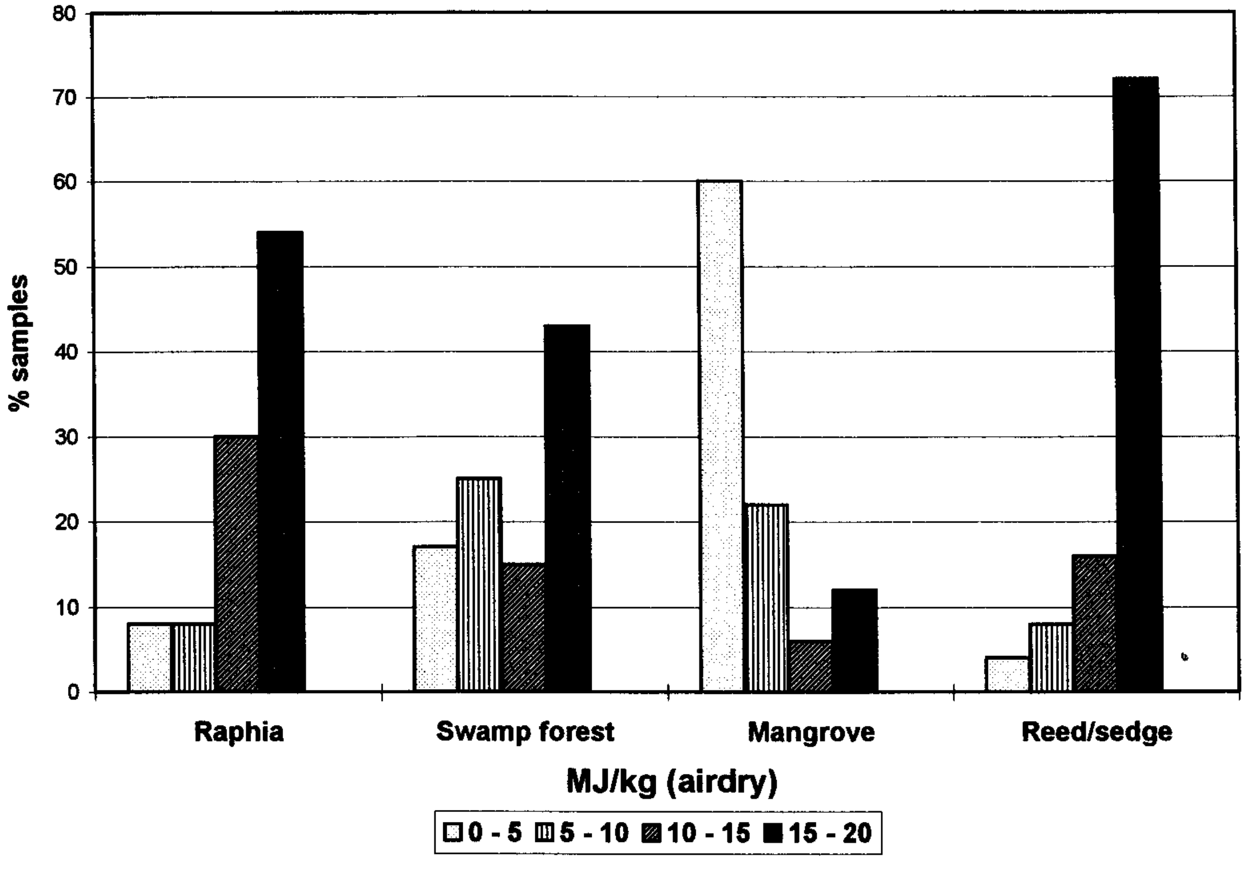
Increasing depth leads to a slight increase in calorific value (MJ/kg) for all peats, but with a low correlation coefficient between the two variables (Fig. 5.19). There was only a small difference in calorific value among the various peat types: swamp-forest peats had the highest average values, and mangrove peat had the lowest average calorific value (Fig. 5.20).

All NMC peat types demonstrated a general trend of increasing calorific value with increasing fixed carbon content, in agreement with the empirical relationship CV (MJ/kg) = 0.34FC + 0.18VM, where FC = % fixed carbon and VM = % volatile matter (Fig. 5.21). The line representing the normal trend for FC vs CV (daf) seems to separate peat types which are richer in combustible hydrocarbons from those which are richer in incombustible volatiles. Sedge/reed peats exhibit a strong tendency towards being perhydrous (rich in combustible hydrocarbons). Swamp forest and mangrove peats plot close to the "normal trend", while *Raphia* peats tend to be subhydrous.

5.1.5.4 Fischer Assay.

It can be expected that a correlation would exist between tar yield and hydrogen content. Inspection of the ultimate analyses and tar yields of these peats seems to point this out. However, only two ultimate analyses and the corresponding Fischer assays of NMC peats have been done (Appendix 3).

Fig. 5.20 Calorific Value (MJ/kg, air dry) for the dominant NMC peat types



5.1.5.5 Bulk density and water holding capacity (absorbency)

Field moisture, bulk density and water holding capacity of the dominant peat types are listed in Table 5.6. Mangrove peats showed the highest bulk density and lowest field moisture content. This is due to two factors, namely, the high ash content of the peat and the relatively high bulk density of the peatforming plants. Sedge/reed and Raphia peats have the lowest bulk density and highest field moisture because the peat formers in both cases are high volume/low density plants that tend to absorb a lot of water once the waxy outer layers of the cuticles are removed during the humification process. Forest peat has a slightly higher bulk density due to its wood content, some of which are hard woods, hence the somewhat lower field moisture.

All South African peat types fall well above the minimum water holding capacity limits as stipulated for horticultural peats in the USA (cf. Table 8.3). Sedge/reed peat, which is the only peat currently being harvested in southern Africa, has an average water holding capacity that is 410 % higher than the minimum listed.

5.1.5.6 Fibre content.

Fibre content and fibre length are dependent on both the type of peat forming plants and the state of humification of the peat. Thus a reed/sedge peat at surface may be classified as fibric (>66% fibre) but with depth the fibre content decreases, the peat becoming hemic (34 - 66% fibre) and eventually sapric (fibre <33%). Palm peats are generally sapric, swamp forest peats range from sapric to fibric, reed/sedge peats are hemic to fibric and mangrove peats show no apparent trend.

Fibre content is generally divided into three percentage classes for the sake of simplicity, viz. 0-33, 33-66 and 66-99 %.

TABLE 5.6 PHYSICAL CHARACTERISTICS OF THE MAJOR PEAT TYPES

Peat type	Field moisture (%)	Bulk density (g/dm^3)	Water holding capacity (%)
Sedge/reed	89.65	12	910
Forest	84.2	14	604
Raphia	95.35	8	2275
Mangrove	67.60	30	286

5.1.6 Mineral matter

5.1.6.1 Mineralogical composition.

Samples of the dominant peat types in South Africa were analysed for mineralogical composition (Table 5.7, Fig. 5.22). These mineralogical analyses reflect the geology of the provenance from which water flows into the mires. The greater part of Maputaland comprises Recent wind-redistributed grey sand (Maud, 1979). These sands are extensively leached, resulting in infertile sandy soils containing mostly quartz and minor (less than 10%) feldspars and clays. Some marine influence was indicated for the hardwood mire early in its history by the presence of illite/smectite clays. The same holds true for mangrove and Raphia peats. The mangrove peats were very rich in illite/smectite clays. These mires are fed by the Mfolozi and Msunduzi rivers (carrying clay-rich sediment from the hinterland) and occur in the brackish to saline environment of the St. Lucia estuary.

The pyrite content reported for the Raphia peats (values of up to 46% of the inorganic fraction of the peat) appears to be anomalously high when compared to the % S (Table 5.8). This may be ascribed to:

1. unrepresentative samples for XRD analysis,
2. mineral segregation during sample preparation, or

3. a poor XRD standard.

The reduction of sulphate to sulphide and its subsequent reaction with ferrous iron to produce pyrite is widely accepted to explain the syngenetic incorporation of sulphur as pyrite in peat (Casagrande, 1987). In addition to H_2S, Fe^{2+} ions need to be readily available. Hydrogen sulphide is common in peatlands and the dispersal of clays transported by freshwater in a marine environment will make ferrous iron available for pyrite formation (Casagrande, 1987). Cohen et al. (1984) report that brackish peats tend to have a higher pyrite content than either marine or freshwater peat types.

TABLE 5.7 AVERAGE COMPOSITION (%) OF THE MINERAL MATTER IN FOUR PEAT TYPES. (X-ray diffraction analysis of inorganic fraction only).

MINERAL	FOREST n=31	MANGROVE n=20	REED/SEDGE n=11	RAPHIA n=7
Quartz	94	50	93	62
Microcline	2	2	1	2
Plagioclase	1	7	2	
Kaolinite		3	tr	4
Smectite	1			
Ill./Smec.		32		7
Calcite/gypsum			2	
Pyrite	2	6	1	25
Hematite			1	

5.1.6.2 SULPHUR CONTENT.

Peat contains all the forms of sulphur that occur in coal. This include pyritic, sulphate and organic sulphur (Casagrande et al., 1977; Given and Miller, 1985; Casagrande, 1987). The average and ranges for total sulphur for various peat types are listed in table 5.8 along with calculated pyrite contents. The relationship between depth and sulphur content for a Raphia mire is shown in figure 5.24. Note that values tend to increase with depth. The anomalously high value at the surface of core 12/2 cannot be explained. Figure 5.22 or Table 5.7 reveals a very high pyrite content for certain horizons within Raphia peat.

Fig. 5.21 Calorific value versus fixed carbon for the Natal Mire Complex

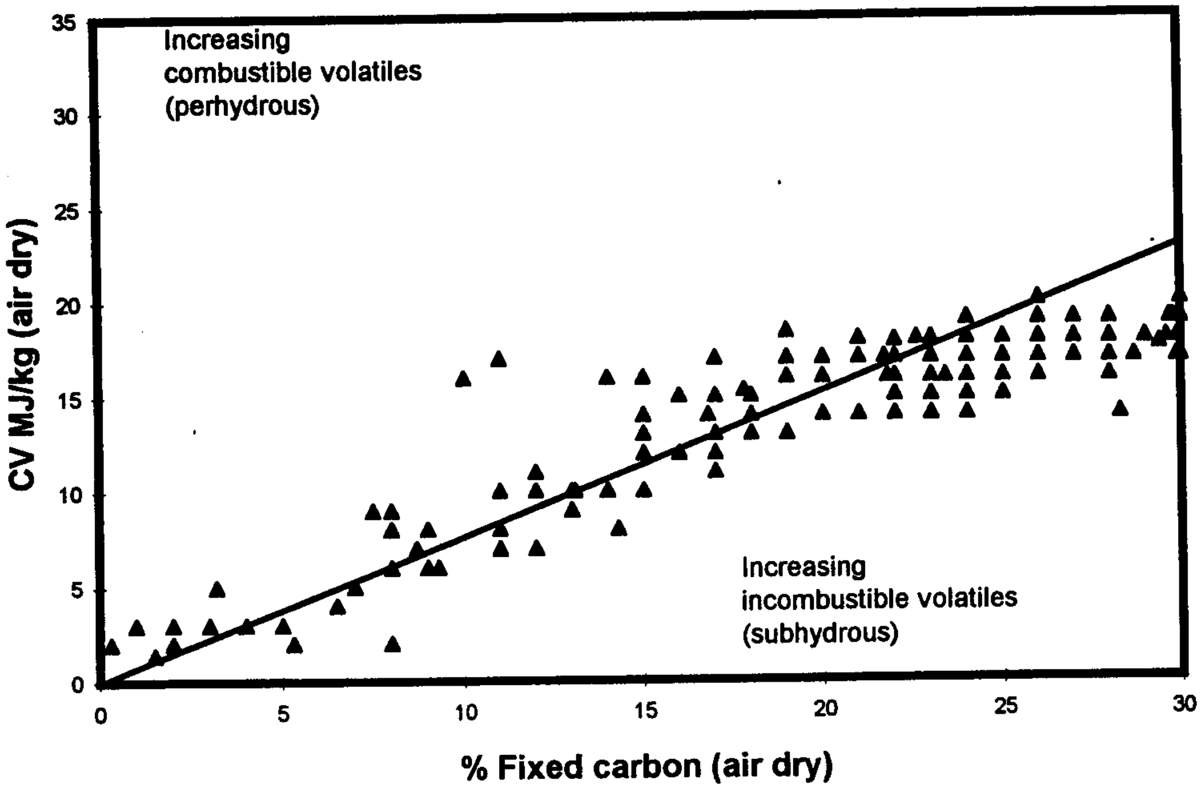


Fig. 5.22 Average composition of the mineral matter in NMC peat

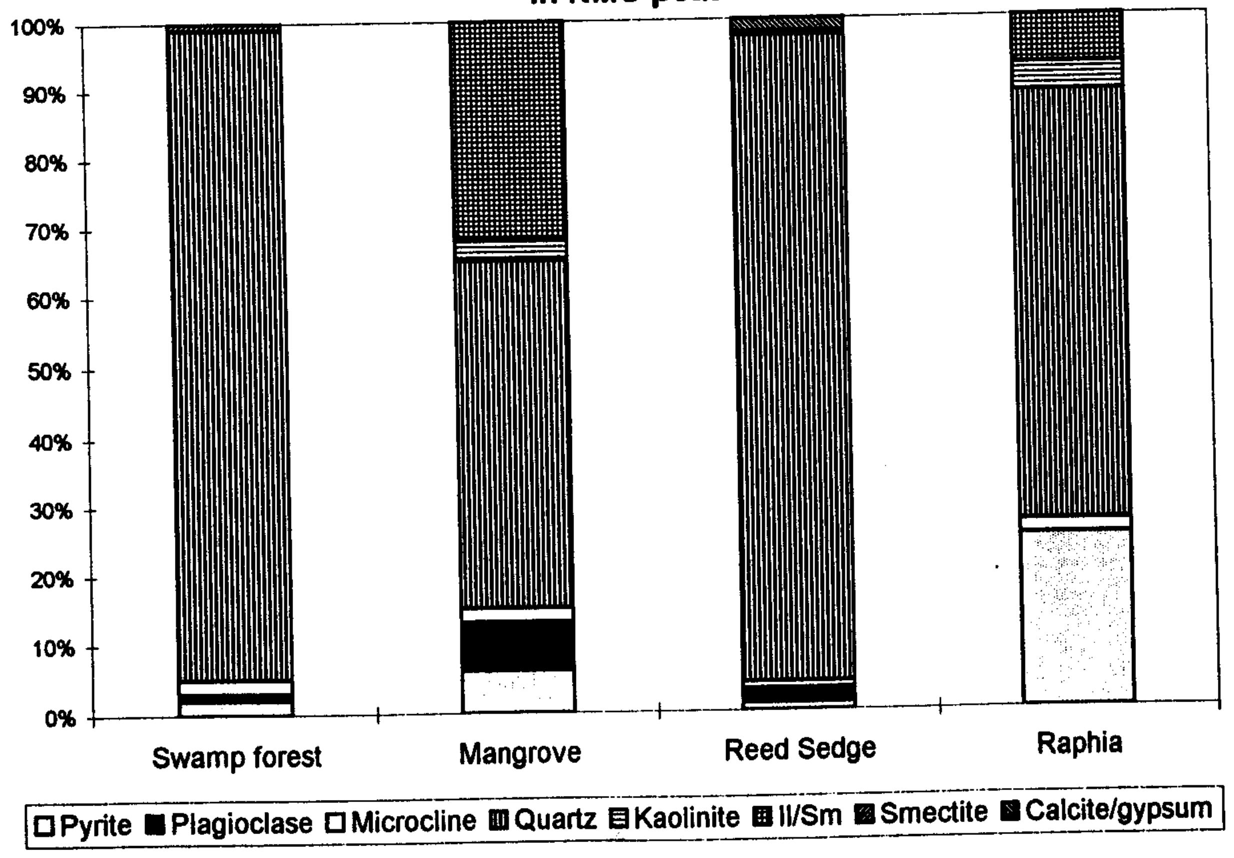


TABLE 5.8 SULPHUR CONTENTS AND CALCULATED PYRITE CONTENTS FOR NMC PEATS (only whole peats with ash contents <50 % were analysed).

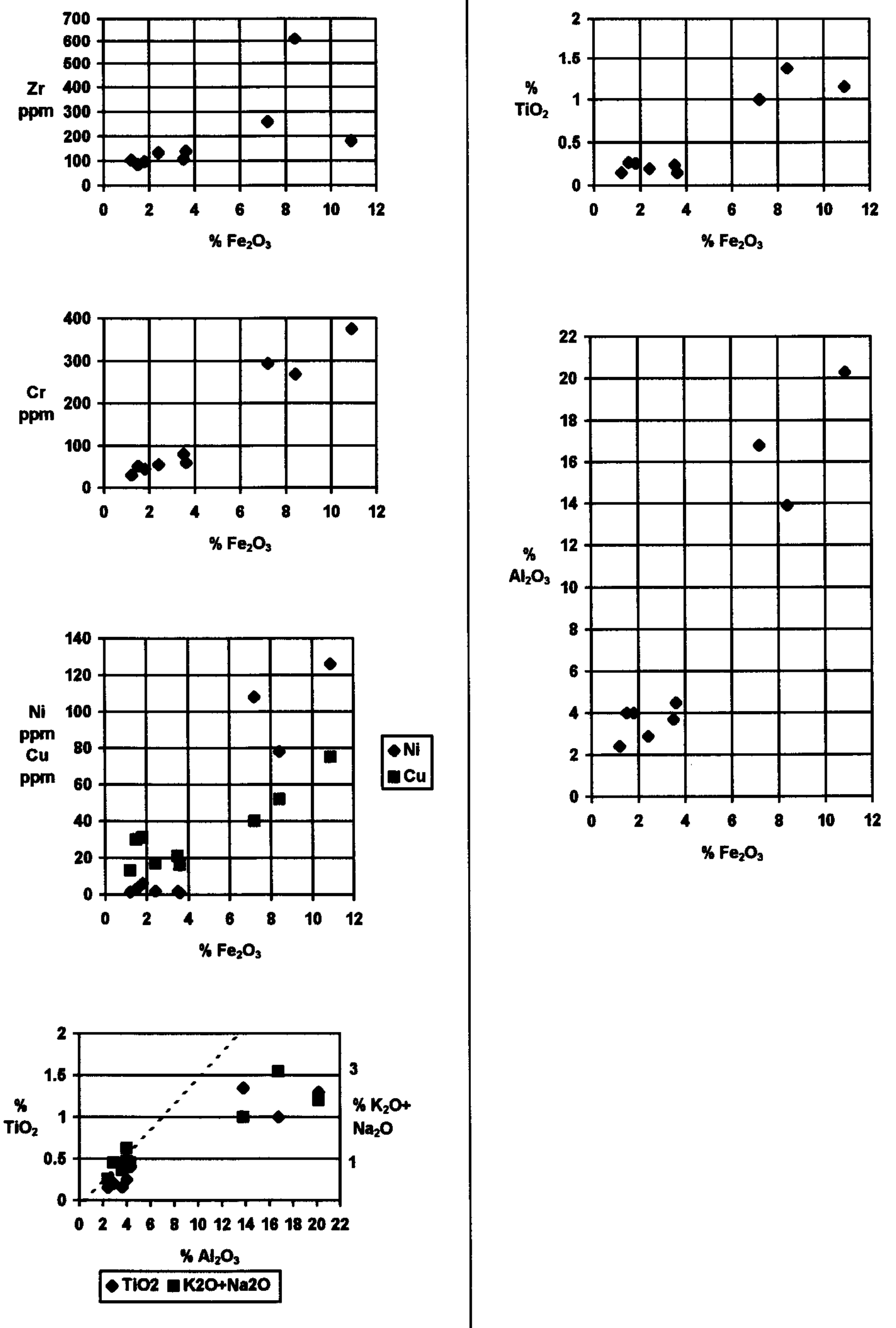
Peat type	n	average %	range	FeS_2 range
Sedge/reed	4	0.24	0.26 - 0.33	0.50 - 0.62
Raphia	29	0.82	0.01 - 4.15	0.03 - 7.77
Forest	5	0.31	0.07 - 0.60	0.15 - 1.13

5.1.6.3 Ash analyses

The average trace and major element concentrations in ash of NMC peats are given in Tables 5.9 and 5.10. In Fig. 5.24a and 5.24b the average concentrations in the ash of different peat types are compared in terms of percentage deviation from the mean of all NMC samples. Mangrove peats are relatively enriched in all major elements except SiO_2 and S; forest peats are impoverished in all major elements except SiO_2 and reed/sedge peat are enriched in Al_2O_3, MgO, CaO and Na_2O (Fig. 5.24a). Mangrove peats are also relatively enriched in all trace elements except Mo, whereas Raphia peat is enriched in Mo, Sr and Y relative to the average. The other peats are impoverished in the trace elements listed (Fig. 5.24b).

Among the major elements positive correlations exist between Fe_2O_3, TiO_2, Al_2O_3, (Na_2O + K_2O), suggesting that these elements are to a considerable degree of clastic origin, either in the form of heavy minerals (ilmenite, rutile, magnetite) or as clastic clay minerals and/or alkali feldspars (Fig. 5.23). On the other hand, no correlation exists between CaO and Al_2O_3, showing that calcium-rich plagioclase is not an important clastic mineral in the peat.

Fig. 5.23 Correlations between major elements and trace elements in peat ash.



(- - - -) Illite ratio (K_2O : Al_2O_3)

Al_2O_3 is also strongly correlated with Ga, as the latter proxies for Al in most silicate structures. Al_2O_3 is also positively correlated with V and Y, and Fe_2O_3 with Zr and Cr, indicating that these trace elements occur as clastic mineral grains (zircon and chromite) or replace major elements in the clastic grains, e.g. Y in zircon and V in magnetite. The positive correlation between Sr and CaO is explained by the fact that Sr proxies for Ca in carbonate minerals, and similarly Ba and Rb are accomodated in potassium minerals. The chalcophile elements Cu, Ni, Pb and Zn are fairly strongly correlated with each other and also to some extent with Fe_2O_3, suggesting that these trace elements and a portion of the iron are accomodated in pyrite.

TABLE 5.9 AVERAGE TRACE ELEMENTS FOR NMC PEATS. Transvaal and Cape reed/sedge peat values included for comparison (all values in ppm from pressed ash pellets).

Element	Tvl R/S (n=18)	Cp R/S (n=5)	NMC R/S (n=4)	Forest (n=8)	Raphia (n=10)	Mangrove (n=3)	Std. Dev.	Average	Correlation with ash
Ba	363	207	258	168	279	473	128	291	0.91
Cr	332	181	54	30	62	324	156	164	0.67
Cu	67	31	16	13	19	63	34	35	0.74
Ga	20	12	8	8	9	24	10	14	0.88
Mo	5	6	6	4	9	5	2	6	-0.32
Nb	15	14	7	<5	6	19	6	11	0.84
Ni	120	39	<1	<1	<1	102	38	44	-0.81
Pb	25	15	9	7	11	26	9	16	0.89
Rb	63	35	23	13	22	110	41	44	0.89
Sr	65	162	100	90	127	111	32	109	-0.56
Th	12	9	<5	<5	5	15	6	9	0.96
U	18	16	13	13	16	16	2	15	0.60
V	193	131	55	28	65	251	121	121	0.77
Y	40	40	26	17	36	51	15	35	0.88
Zn	82	104	21	14	22	89	30	55	0.62
Zr	233	435	139	107	126	397	160	240	0.38

TABLE 5.10 AVERAGE MAJOR ELEMENT ANALYSES OF PEAT ASH AND THE STANDARD DEVIATIONS.

Element	Transvaal R/S (n=18)	Cape R/S (n=5)	NMC R/S (n=4)	NMC Forest (n=8)	NMC Raphia (n=10)	NMC Mangrove (n=3)	NMC all peats (n=25)
SiO_2	80.66	88.73	79.27	93.79	89.54	67.80	83.46
Std. Dev.	33.97	2.64	12.76		0.62	7.62	30.35
TiO_2	0.44	0.84	0.40	0.02	0.19	1.27	0.40
Std. Dev.	0.34	1.07	0.05		0.06	0.15	0.49
Al_2O_3	8.73	4.19	6.65	0.45	3.92	16.99	5.94
SD	7.78	1.97	1.05		0.39	4.47	6.54
FeO(t)	3.85	1.59	2.72	0.2	3.48	9.58	3.58
SD	3.68	1.53	0.49		0.03	1.99	3.63
MnO	0.64	0.02	tr	tr	tr	0.06	0.03
SD	0.19	0.03				0.01	0.03
MgO	2.63	0.69	0.84	0.09	0.36	1.28	0.54
SD	0.56	0.38	0.03		0.02	0.27	0.43
CaO	2.35	2.79	1.72	0.27	2.16	1.43	1.21
SD	2.13	3.42	0.005		0.60	0.28	0.70
Na_2O	0.13	0.22	0.32	0.01	0.1	0.36	0.23
SD	0.13	0.23	0.15		0.00	0.007	0.14
K_2O	0.26	0.28	0.50	0.07	0.70	1.26	0.62
SD	0.23	0.26	0.08		0.11	0.89	0.54
P_2O_5	0.2	0.17	0.05	0.01	0.17	0.14	0.09
SD	0.16	0.03	0.03		0.007	0.007	0.06
S	0.11	0.19	-	0.05	0.55	0.11	0.29
SD	0.05	0.18			0.29	0.04	0.24

Fig. 5.24 Sulphur (%) versus depth in a Raphia mire.

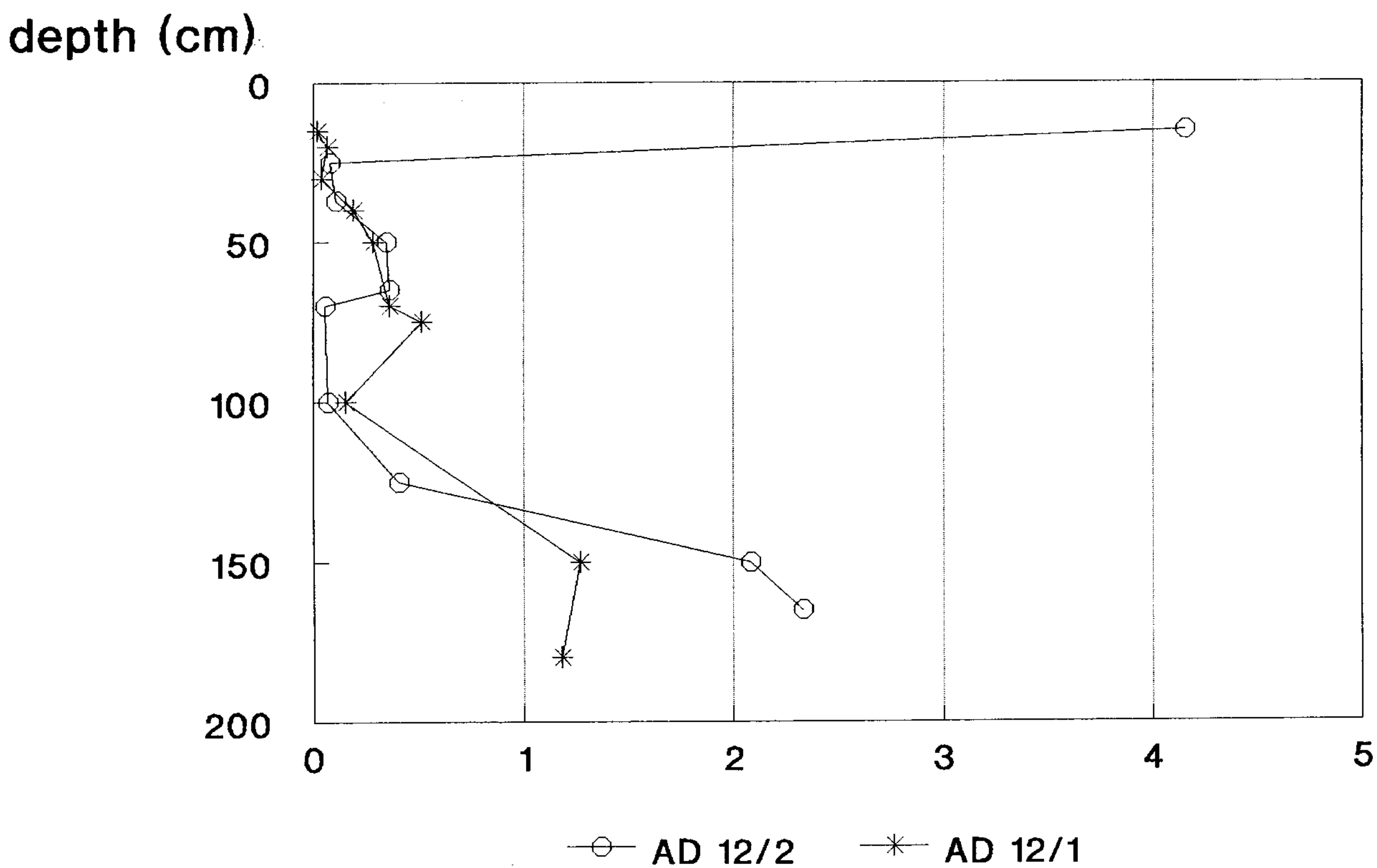


Fig. 5.24A % Deviation from the mean for major elements in the NMC

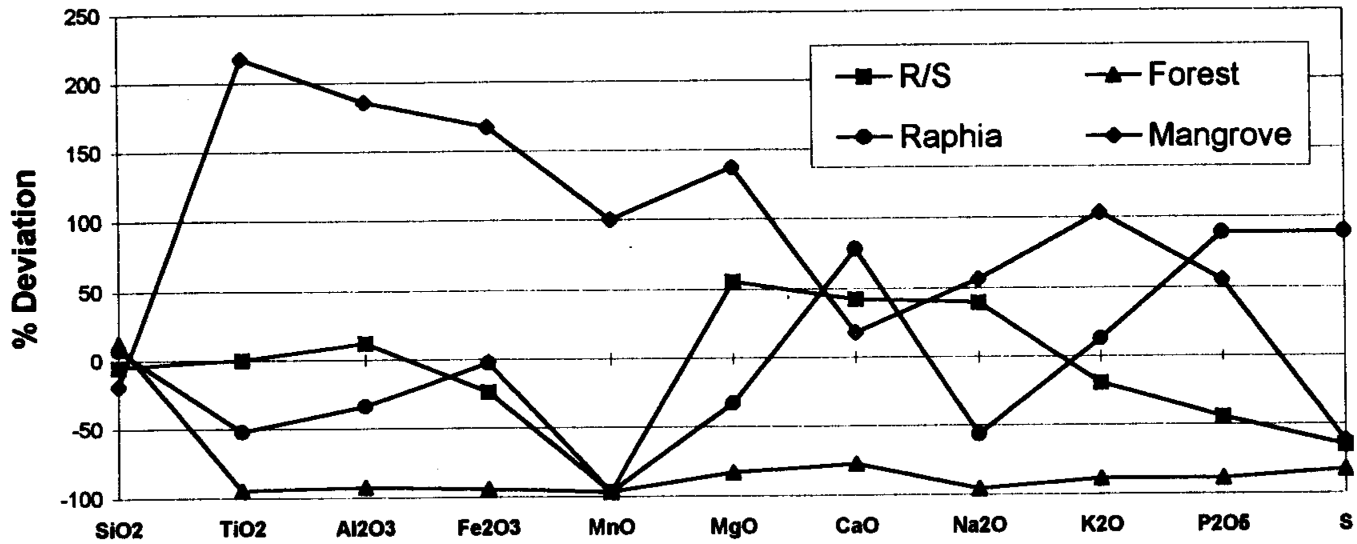
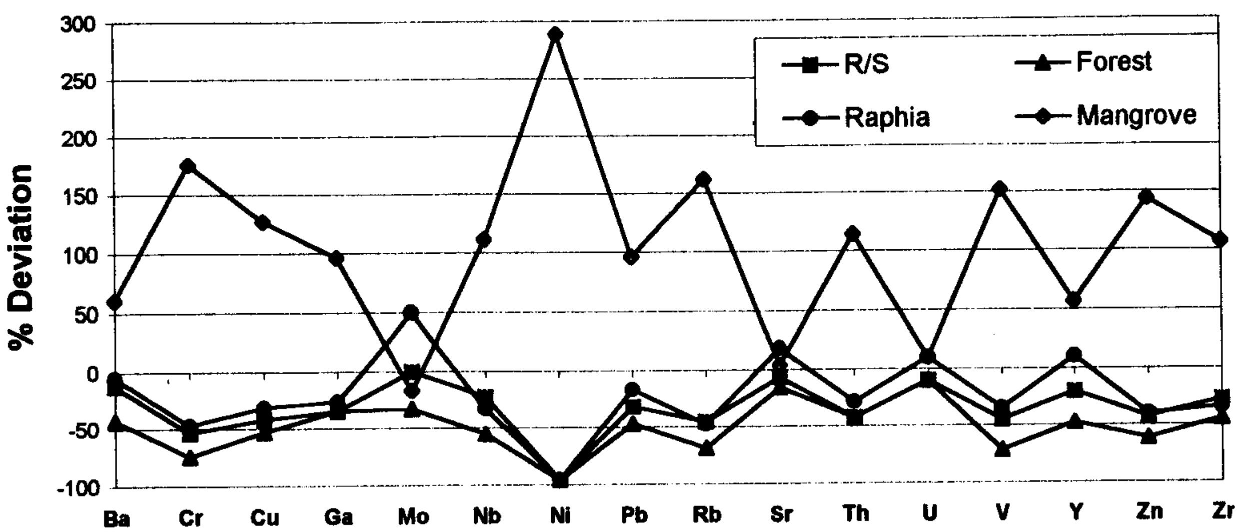


Fig. 5.24B % Deviation from the mean for trace elements in the NMC



5.1.7 Conditions of peat formation.

The fact that the rate of decomposition of organic material in a wetland fails to keep pace with production results in peat formation, the rate of which will be dependent on the ratio of these two processes. Peat accumulation in any system is a slow process; figures quoted in the literature vary from 20 to 80 cm in 1000 years (Walker, 1970). It should however be noted that these figures are valid for northern hemisphere peatlands. Radiocarbon dates from a Costa Rican peatland indicate an accumulation rate of 1 m per 800 years (Cohen et al., 1985). Accumulation figures quoted for southern Africa are 5 cm per year in the Okavango swamp (Cairncross et al., 1988) and 10 cm per year in an eastern Transvaal spring mire (measured over a ten year period) (Mr. J. Du Plooy, pers. comm., 1988). These figures are observations of present-day accretions.

One of the most effective ways of estimating the rate of peat accumulation over extended time periods is by obtaining dates for specific stratigraphic layers from the peat profile and to calculate rates of peat build-up from these figures.

However, this method has certain disadvantages.

1. Dating is not an easy procedure and may be inaccurate. Radiocarbon dating is the best available technique but may have wide errors if peat samples are penetrated by roots from above or the samples are contaminated in any way. Pollen analyses can be used with radiocarbon dating to extrapolate pollen zones that may be synchronous in other peat profiles.
2. As new material is laid down on the peat surface, lower peats are compacted. Deeper layers are also more tightly compressed than shallower layers. Hence, radiocarbon dating may create an untrue picture of modern seasonal peat accumulation rates.
3. Rates of formation are expected to vary with climate and since climate is in a constant state of flux peat accretion rates during different periods in the past cannot be compared.

Bearing the above problems in mind it is however interesting to look at some figures for the northern Natal Mire Complex.

Peat samples from various localities were dated using the ^{14}C method (Table 5.11). The number of dates were however severely curbed by financial constraints, with the result that the number of data points are less than satisfactory. Indications from these dates are that the latest peatforming period in coastal Natal was already well underway 4800 years ago. Peat accumulation was continuous, albeit at changing rates, during this period.

TABLE 5.11 RADIOCARBON DATES FOR SOME SOUTH AFRICAN PEATS (determined by EMATech, CSIR).

Analysis number.	Sample with depth	^{14}C age (yrs BP)	LOCALITY
Pta-5250	Mgobezeleni 85 cm	130 ± 45	27° 32'S; 32° 40'E
Pta-5254	Mgobezeleni 93 cm	450 ± 40	"
Pta-5253	Mgobezeleni 143 cm	1100 ± 40	"
Pta-5256	nHlange 235 cm	4840 ± 100	27° 07'S; 32° 49'E
Pta-6373	Sibayi 140 cm	770 ± 50	27° 22'S; 32° 44'E
Pta-6370	Sibayi 550 cm	4120 ± 60	"

Figures for compaction of peats cited in literature range from 15% to 44% (Stout and Spackman, 1989). Applying an average compaction of 35% to NMC peats would modify the rates of formation as shown in tables 5.12 and 5.13. The cummulative accumulation rate in these tables is based on the assumption that the peat thickness is represented by the time interval between the maximum age and the present in each case. The interval accumulation rate is based on the peat thickness resulting from subtracting the thickness of the younger age from that of the older age.

TABLE 5.12 RATES OF PEAT ACCUMULATION IN THE NATAL MIRE COMPLEX ($mm.yr^{-1}$). No correction made for compaction.

	interval (years)	interval (thickness, cm)	interval ($mm.yr^{-1}$)	cumulative ($mm.yr^{-1}$)
4120 - 1100 BP	3020	407	1.35	1.33
4840 - 1100 BP	3740	92	0.25	0.49
1100 - 450 BP	650	50	0.77	1.30
450 - 130 BP	320	8	0.25	2.07
130 - 0 BP	130	85	6.54	6.54

TABLE 5.13 RATES OF PEAT ACCUMULATION IN THE NATAL MIRE COMPLEX ($mm.yr^{-1}$). Corrected for compaction.

	cumulative
4120 - 1100 BP	2.05
4840 - 1100 BP	0.75
1100 - 450 BP	2.00
450 - 130 BP	3.18
130 - 0 BP	10.06

If we keep the potential disparity between the estimated compaction and the actual compaction in mind, the rate of accumulation could actually be much higher. If we also consider that most southern African peatforming genera are high volume, low density plants (reeds, sedges, palms) that are highly susceptible to compaction, the discrepancy between estimated and actual compaction is further highlighted. This could support the findings of Cairncross et al. (1988) and of Mr.. J. Du Plooy (Pers. Comm., 1988) of accumulation rates of between 5 and 10 $cm.yr^{-1}$ for modern peats in southern Africa.

It is further important to recognise the vast difference between peat accumulation rates in the context of geological time and the current addition of biomatter to the top of the acrotelm.

5.2 *Inland Valley Mires*

Inland valley mires are the most common mire type found in South Africa and occur in all regions except the Northern Cape. They tend, however, to develop mostly in the eastern sector of the country which is the cooler, higher rain-fall area. The most notable peatlands occur in the eastern and southern Transvaal, eastern Orange Free State, the midlands of Natal and the south-western Cape. The largest inland valley mires occur in the Natal midlands, eg. Mvoti Vlei, 2800 ha (Fig.4.1 no11, 29°09'S/30°35'E) and Blood River Vlei, 6540 ha (Fig.4.1 No12, 27°49'S/30°34'E), while the largest number of individual mires, albeit generally smaller, occur in eastern Transvaal (Mpumalanga) along the escarpment, for example on the 1:50 000 topographic sheets:

- BELFAST 2530 CA, 94 wetlands with a combined area of 61.87 km^2
- LOTHAIR 2630 AD, 34 wetlands " " area of 45.94 km^2
- DIRKIESDORP 2730 AB, 102 wetlands " " area of 96.37 km^2
- WAKKERSTROOM 2730 AC, 85 wetlands " " area of 38.81 km^2.

It is generally found that less than one third of these wetlands contains economic peat reserves, i.e. peat with a thickness in excess of 0.5 m and a surface area of at least 10000 m^2. The following inland valley mires were considered in this study:

Klip River	Figure 4.1	No 14
Wakkerstroom		No 16
Rikasrus		No 29
Lakenvlei		No 18
Gerhard Minnebron		No 28
Goergap		No 30

5.2.1 Geomorphological setting.

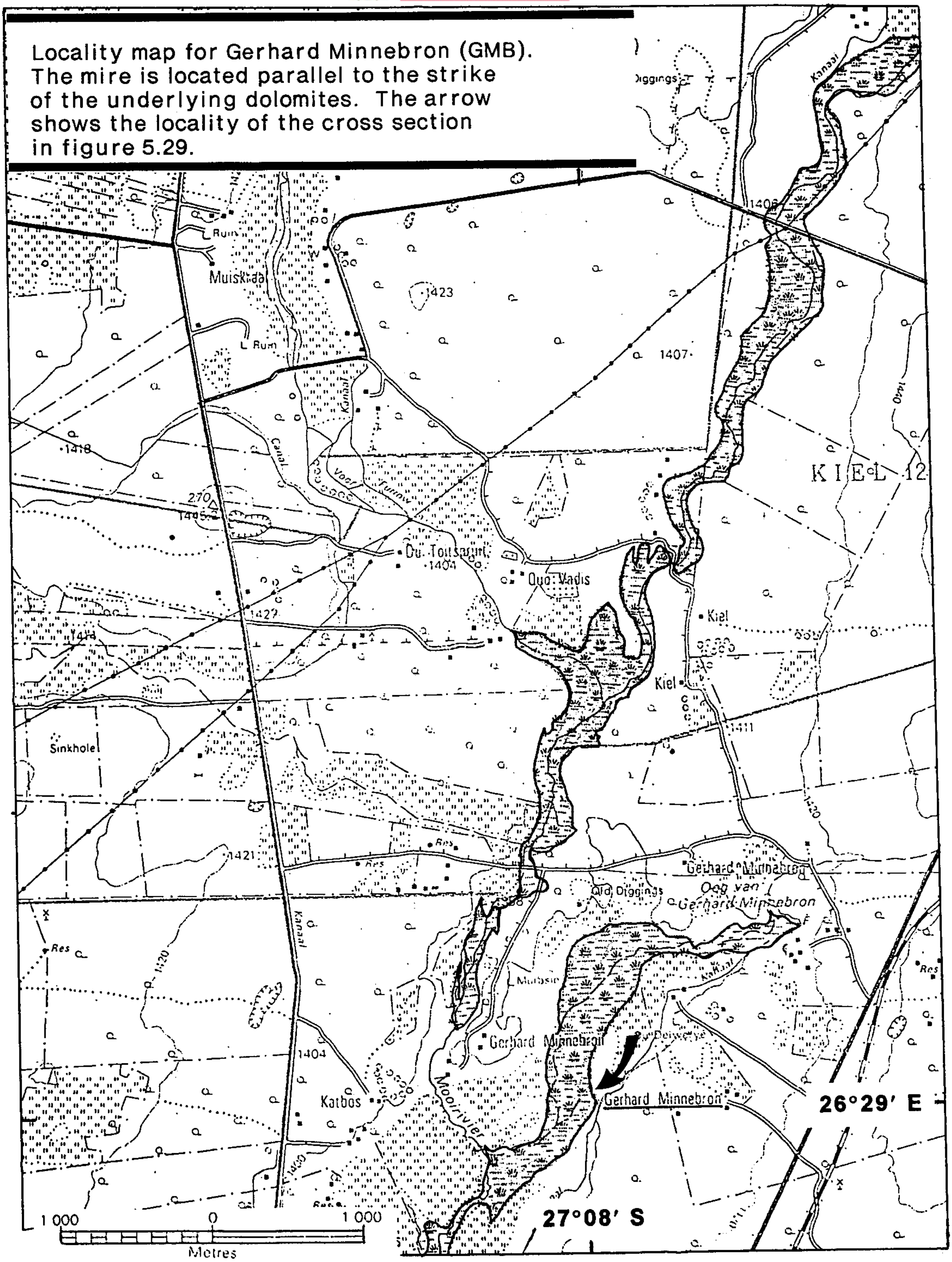
Valley mire peats were deposited in valleys behind obstructions generally associated with resistant geological outcrops. The obstructions result in drainage impediments which in turn lead to slower water and enhanced vegetation growth. These mires, because of their position at the lowest position in the local topography, generally tend to form simple or complexly branched elongated bodies - depending on the size and geomorphological nature of the host-valley and the mire itself (compare Figs 5.25 and 5.26 with Figs 4.8 and 4.9).

5.2.2 Vegetation

Vegetation in valley mires is similar, at least in terms of the dominant peat forming plants, irrespective of where they occur in South Africa. The dominant peat formers are usually various combinations of the common reed (*Phragmites australis)* and/or bull rush (*Typha capensis*), various sedge species (*Schoenoplectus corymbosus, Mariscus congestus*, etc.), lesser grasses (*Imperata cylindrica, Andropogon eucomus, Leersia hexandra, Miscanthus junceus*, etc.) and as substratum of lower vegetation a whole host of smaller herbaceous plants are usually found spread through the mire. Each species tends to occur as pure or near pure stands in the mire depending on the local hydrological conditions and the specific water and light requirements of the particular plant (Fig. 5.27).

5.2.3 Field characteristics of the peat.

In cross-section these peatlands typically present a lens-shaped profile while the thalweg section is usually tabular to cigar-shaped (Figures 5.28; 5.29 and 5.30). The top surface of valley mires appears to be relatively flat featureless expanses at first glance. However, closer inspection will reveal that most are in fact domed. The typical climate and hydrology experienced by most South African mires only allow for low relief doming (less than 100 cm over several hundreds of metres). This doming effect can best be seen during the dry season when vegetation is often burnt off, leaving valley mire surfaces bare for some weeks. In larger mires streams may also migrate across the surface or cut into the peat. Profiles from a number of valley mires are shown in Appendix I.



Locality map for Gerhard Minnebron (GMB). The mire is located parallel to the strike of the underlying dolomites. The arrow shows the locality of the cross section in figure 5.29.

Figure 5.26

Fig. 5.25 Locality map of the larger Klip River Mire south of Johannesburg, its geomorphic expression largely dictated by the contact between the Malmani dolomites and the Black Reef quartzites.

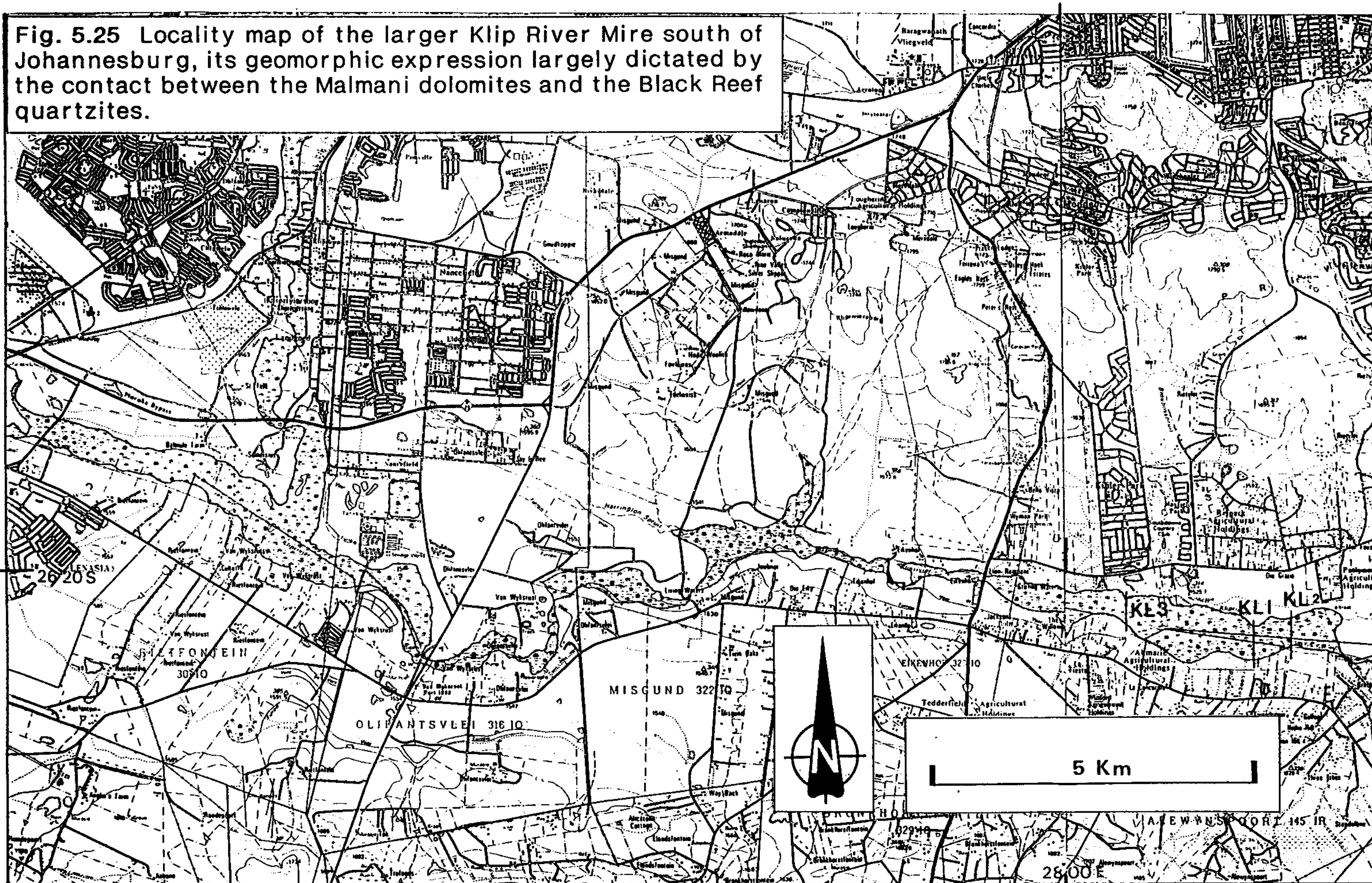


FIGURE 5.27

A). Pure stand of *Typha capensis* in the back-ground. Nearer the edge of the mire (camera position) the bull rush makes way for *Phragmites* and the sedge, *Schoenoplectus*. Peat below the Typha is 2m thick. Note abundant water in pathway. This combination is typical of certain parts of many valley mires, eg. Gerhard Minnebron and Goergap where water levels are high.

B). View obliquely across Klip River Mire near Eikenhof. *Phragmites australis* cover the entire wetland surface with very little other vegetation present for most of the mire. The reeds on the mire are typically 5m high and very dense. The distance across the mire is about 700 m.

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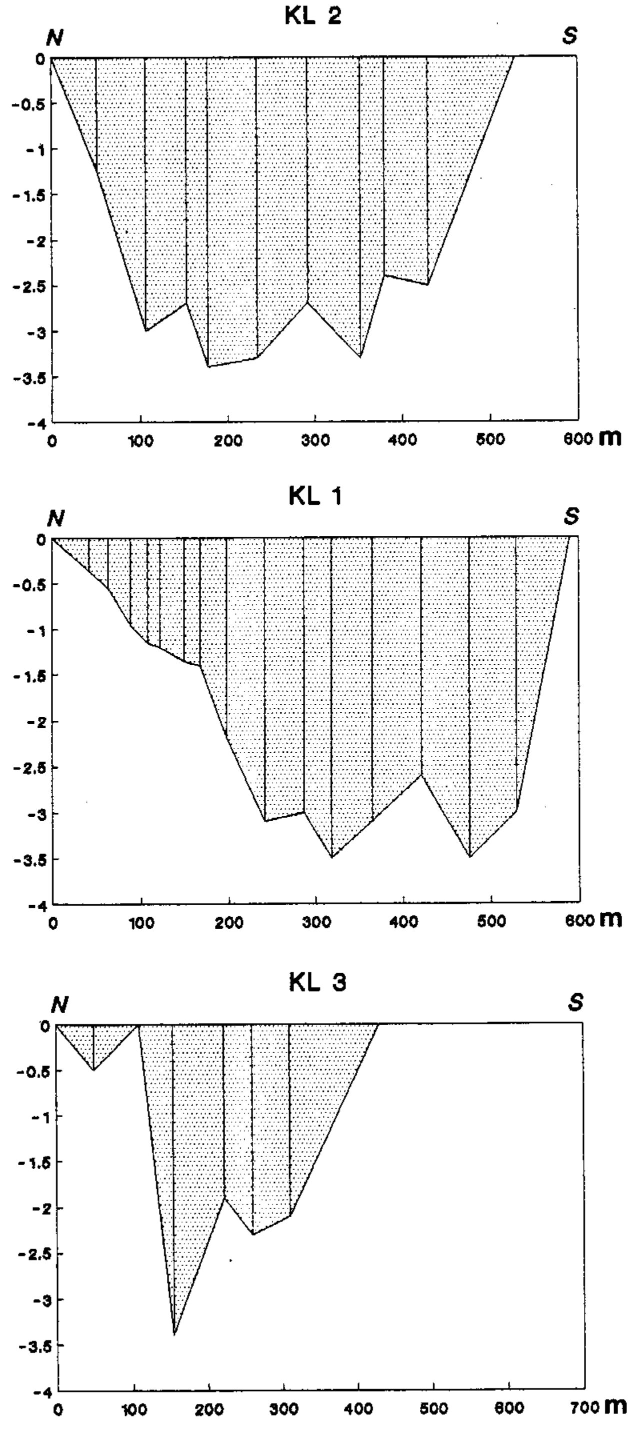
FIGURE 5.27

C). Typical dense, exclusive stand of *Schoenoplectus corymbosus* in a valley mire north of Soweto.

D). A mire where the vegetation is not dominated by one particular species but made up of a number of mostly smaller sedges and grasses. A few flowering herbs, shrubs and ferns may also occur. Distance across the mire ranges from 40 m to 130 m. Examples of this kind of mire are to be found at Rikasrus and Babsfontein.

Fig. 5.28 Cross-sections through parts of the Kliprivier mire



* *See Figure 5.25 for localities of cross-sections.*

Fig. 5.29 East - West sec... Gerhard Minnebron reed/sedge mire.

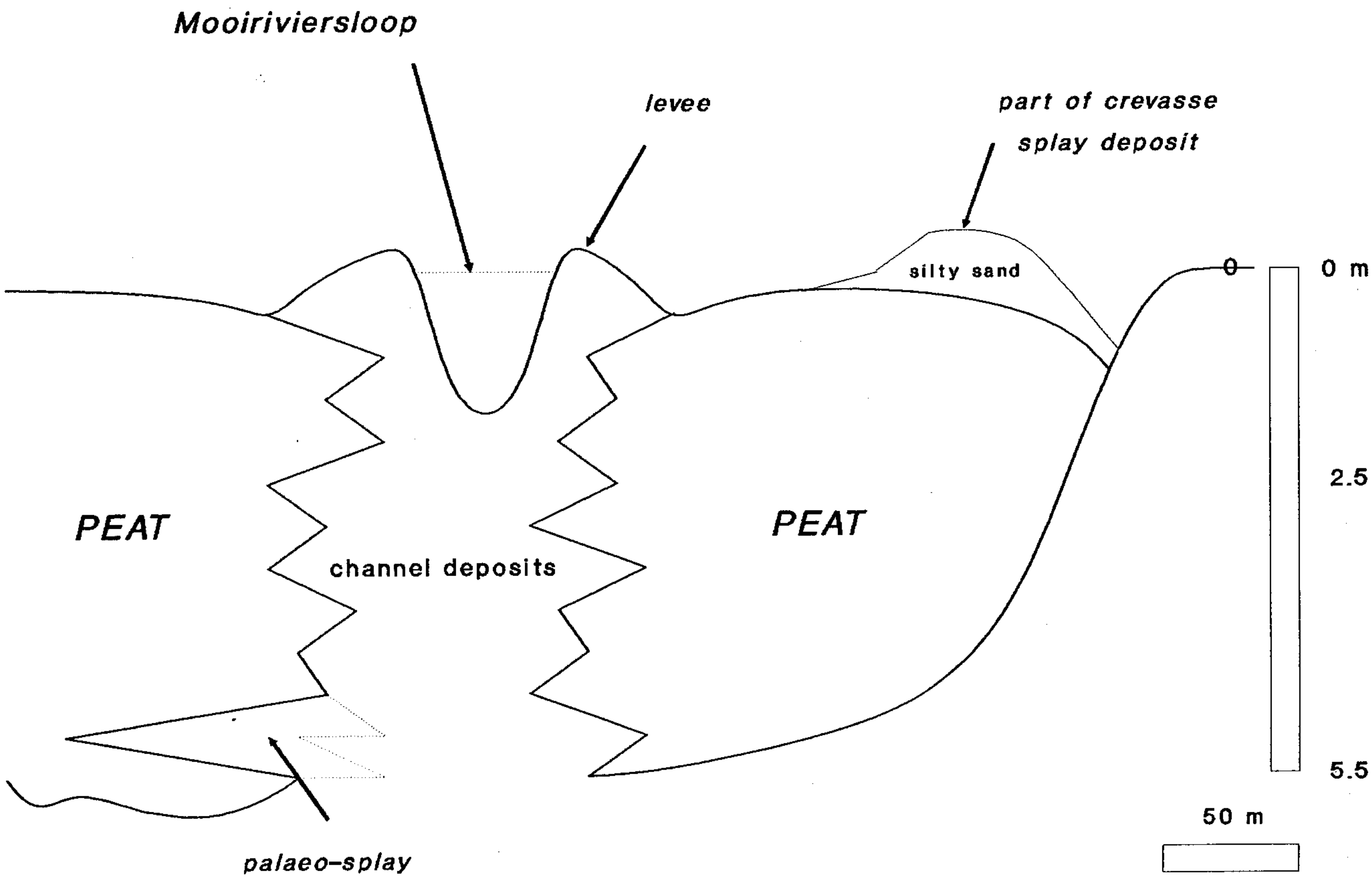
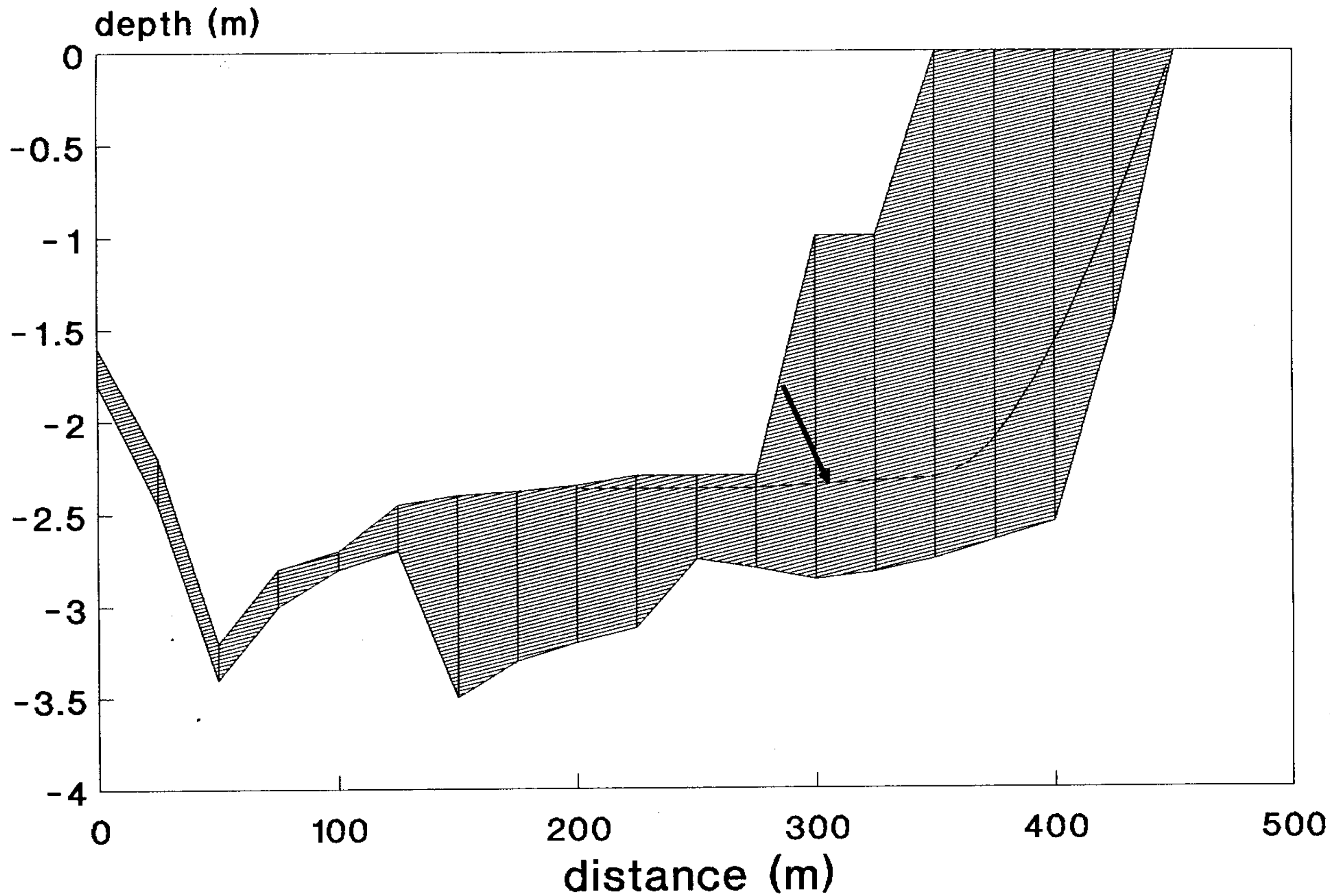


Fig. 5.30 Thalweg section through part of a valley mire being harvested at Rikasrus.



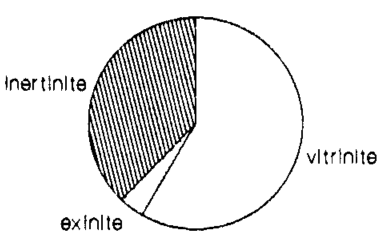
arrow = harvesting limit allowed by Dept. Agriculture.

5.2.4 Peat petrography.

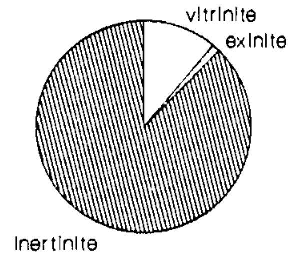
Valley mire peats can all be described as sedge/reed peats. The relatively warm climate and cyclic dry periods in this part of South Africa result in higher oxidation rates in the resultant peats. This in turn leads to relatively high contents of organo-mineral matrix in many peats as a result of the higher oxidation rates and more mineral matter in the form of dust being added to the system. Petrographic analyses of South African valley mire peats indicate the organo-mineral matrix content to range between 2% and 69% (average 36%, see appendix). The petrographic contents of some valley mire peats recalculated free of organo-mineral matrix (for clearer comparison with other peats) are shown in Figure 5.31. Along the left side of Figure 5.31 the change of petrographic composition with depth is indicated for a typical sedge/reed mire (GMB - Gerhard Minnebron, 26°29'40"S/27°08'E). The huminite (vitrinite) content decreases with depth (increasing age) as the inertinite increases. The maceral compositions of Wakkerstroom (Fig.4.1 No16) (-125 cm, a bottom sample) and Goergap (Fig.4.1 No30) (-180 cm, a middle sample) appears to be in accordance; Rikasrus (Fig.4.1 No29) however still reflect a "top" maceral composition; down to its middle levels.

The average maceral composition for all valley mire peats analysed is: vitrinite (46%), inertinite (50%) and exinite (4%). The common occurrence of periodic droughts and subsequent fires in inland valley mires is reflected by the high inertinite contents found in these peats, ranging between 26% and 88%. Inertodetrinite represents the bulk of the inertinite component followed by pyrofusinite. Most of the peat formers in these mires have thin cell walls and fires are usually hot and fast burning. The effect is that the charred remains of the plants tend to be very brittle and they easily disintegrate into small fragments. During the dry season after fires this charcoal and ash are found in layers of up to 30 cm thick on the peatlands. Some charcoal is blown away by the wind but the rest is compacted to approximately 10 - 15 cm. By the time the rains start again more of this, by now loosely compacted, fine charcoal is washed away or redistributed over the mire surface, thinning the layer further to less than 10 cm. New vegetation growth resumes with most of the new roots forming just below this layer.

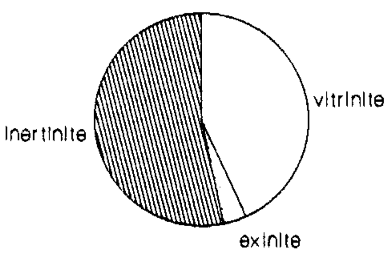
Fig. 5.31 Maceral Composition for Valley Mire sedge/reed peats



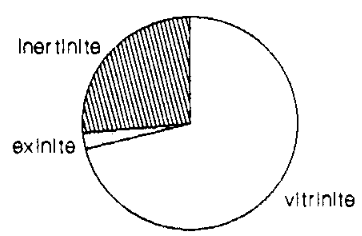
GMB top (-60cm)
Gerhard Minnebron



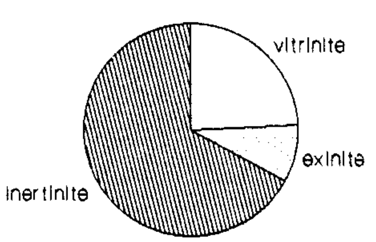
Wakkerstroom (-125cm)



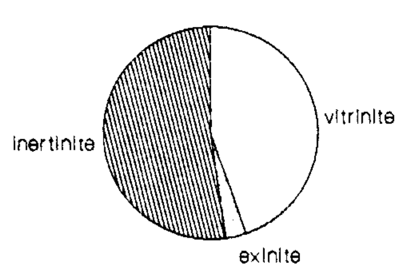
GMB middle (-230cm)



RIK (-180cm)
Rikasrus



GMB bottom (-530cm)



GGP (-180cm)
Goergap

5.2.5 Physical-chemical properties of the peat

5.2.5.1 Proximate analysis.

5.2.5.1.1 Ash

Ash contents in valley mire peats exhibit a typical zigzag pattern with depth alternating between high-ash and low-ash (Fig. 5.32). The straight line on each ash profile represents the mean trend for those peats, excluding the basal (non-peat) sample. Most peats however have ash contents between 10% and 40% throughout any particular profile. The high ash levels may be indicative of two scenarios:

1. fire-episodes in the mire's history or periods of increased drought leading to higher oxidation of the peat and more dust being blown into the system.
2. higher aqueous deposition of inorganic matter after a drought/fire, before the vegetation had time to recover.

The majority of valley mire peats have a tendency of decreasing ash content with an increase in depth. This is probably due to an increase in bulk density so that the organic matter increases with respect to the mineral matter.

5.2.5.1.2 Fixed carbon.

Fixed carbon seems to increase with depth in the peat from Rikasrus (Fig. 5.33). In other cases no correlation is apparent. Very low fixed carbon values (daf) (implying >90% volatiles) are typical of high-ash material (>75% ash)and are most probably an indication of high inorganic volatiles. Ranges for fixed carbon from four different valley mire deposits are shown in Figure 5.34. TP (Tarlton) and GGP (Goergap) have an average FC content of 35% and a higher, narrower range than GMB (Gerhard Minnebron) and RIK (Rikasrus, Randfontein) with an average of 28%. The ash of GMB and TP peats is rich in Fe_2O_3 and CaO, pointing to large amounts of inorganic volatiles due to dissociation of calcite and pyrite -

$CaCO_3 \longrightarrow CaO + CO_2$ and $FeS_2 \longrightarrow FeS + S$.

This would lead to an apparent decrease in fixed carbon, as

fixed carbon (daf) = 100 - volatiles (daf).

Fig. 5.32 Ash/depth profiles for valley mire peats

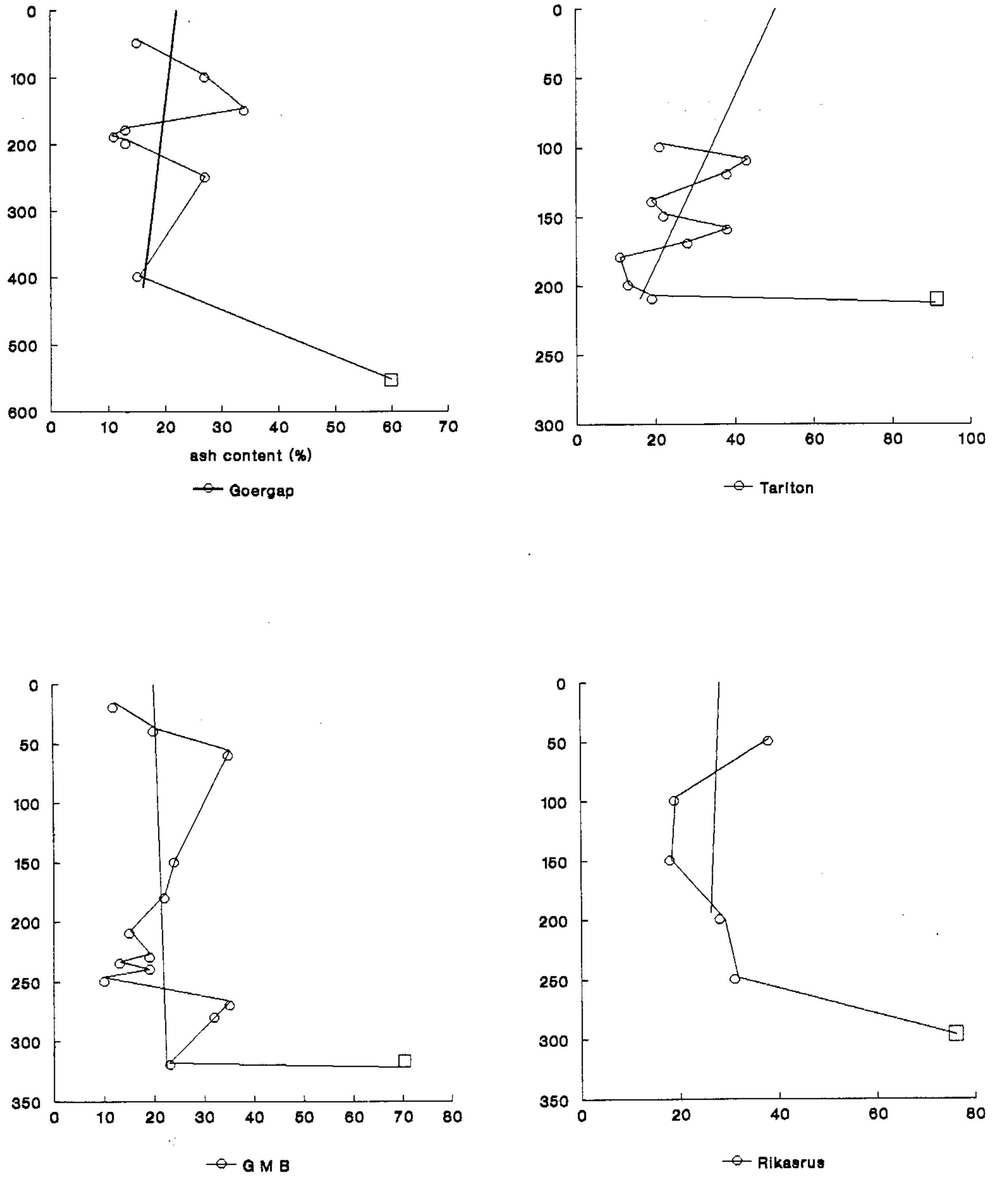


Fig. 5.33 Fixed carbon (daf %) versus depth (cm) for valley mire peats

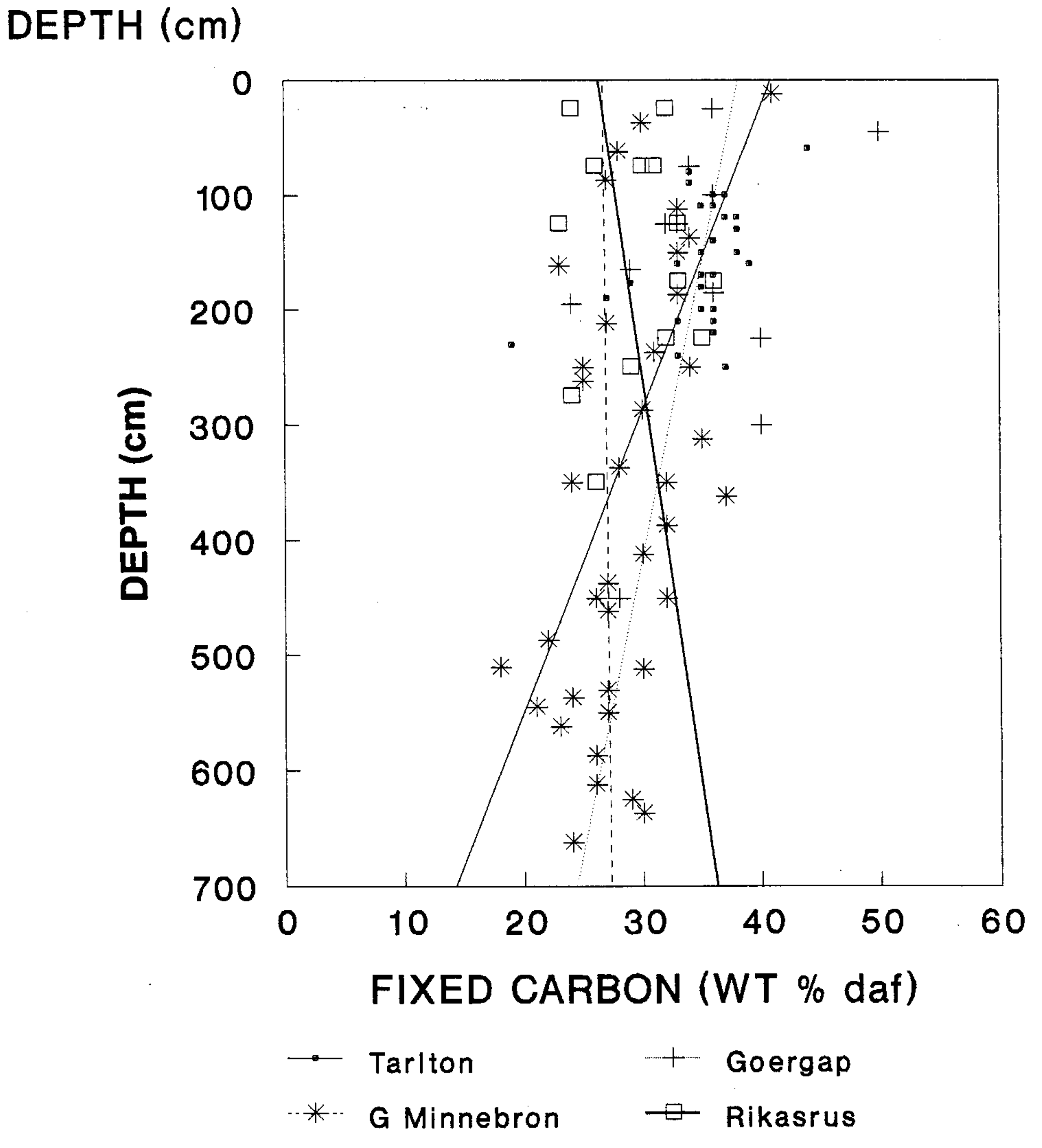
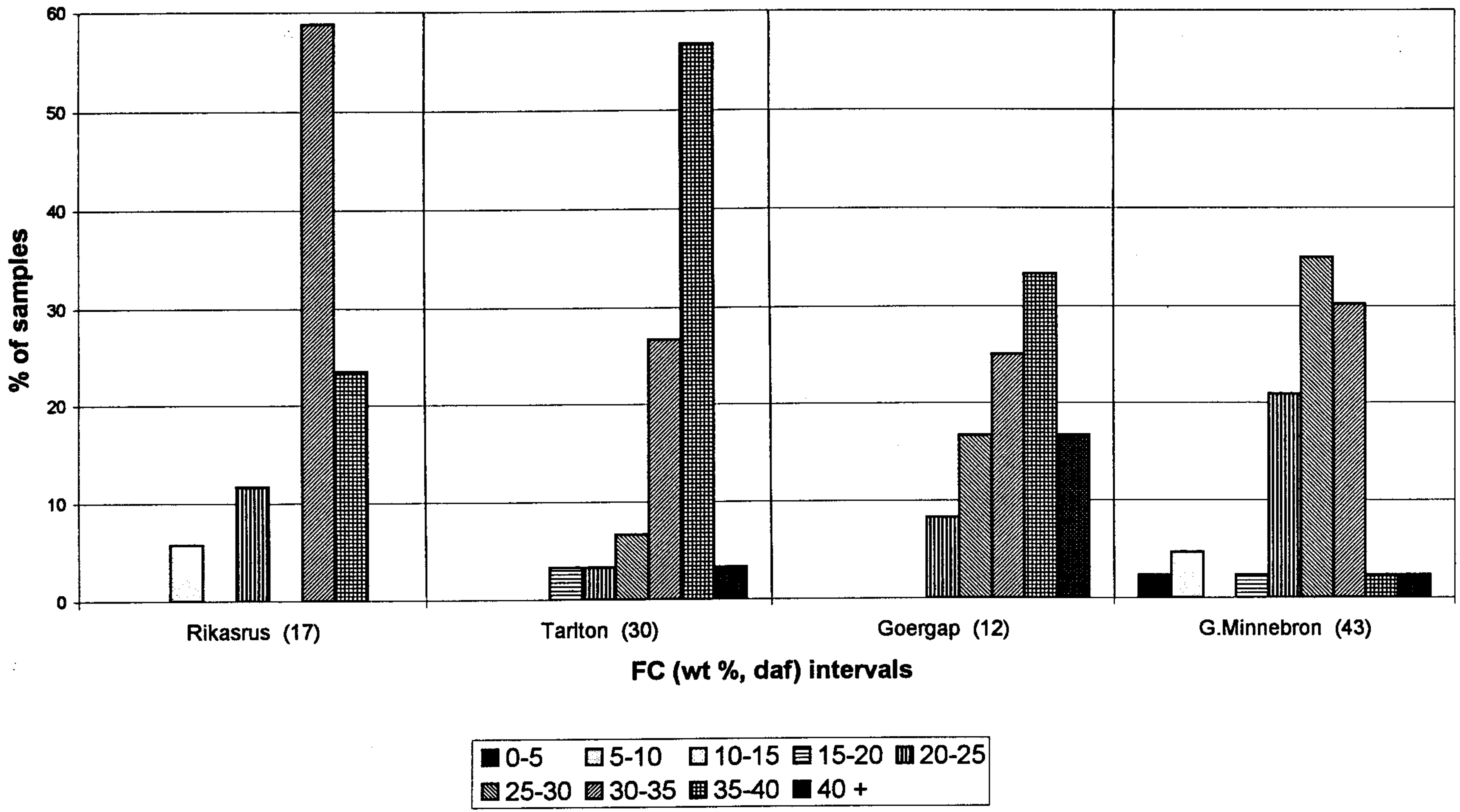


Fig. 5.34 Fixed carbon (wt%, daf) distribution for valley mire peats



5.2.5.2 Elemental analyses.

The elemental analyses of eleven peat samples from inland mires are given in Appendix 3. In only 3 of these the determined calorific value (calculated daf) agrees reasonably well with the values calculated from the elemental analysis and also with values calculated from volatile matter and fixed carbon contents. The 4 analyses marked Gerhard Minnebron also seem to be in order. In paragraph 3.2 it was shown how suspect analyses could be adjusted by means of Boie's formula, but that no unique answers could be obtained (Appendix 3).

By assuming that the O/C ratio has a similar relationship to depth as in the case of NMC peat (Fig.5.18) the relationship in the case of inland mires was found to be:

O/C = 0.91 exp. - 0.0042766D .... (3)

The H/C to depth relationship is assumed to be identical to that of NMC peats, viz.

H/C = 0.116 exp. - 0.001352D .... (4)

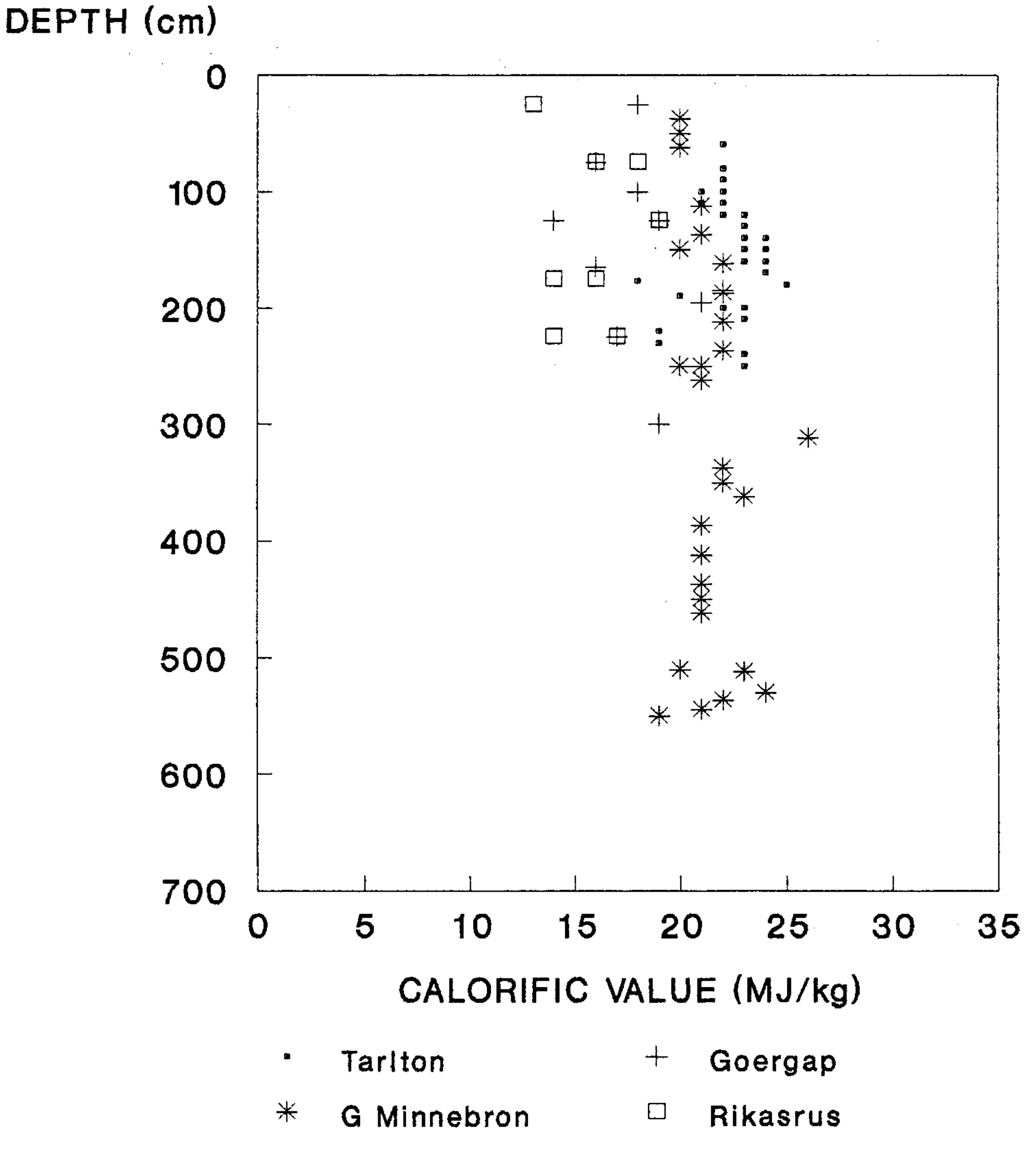
Based on these equations and following the same reasoning as in case of the NMC peats (5.1.5.2), the adjusted elemental analyses and calorific values are listed in Table 5.14.

TABLE 5.14 Adjusted elemental analyses of some inland valley mire peats.

SAMPLE	% C	% H	% O	% N	% S	CV (det.)	CV (calc)	remarks
TP2 @ 150cm	61.24	5.82	29.33	2.20	0.83	24.3	24.6	
RIK @ 200cm	66.25	5.90	25.64	2.01	0.16	23.6	26.7	unacceptable
RIK @ 100cm	57.51	5.81	34.11	2.55	0.08	23.5	22.7	
RIK @ 250cm	69.52	5.77	22.63	1.88	0.06	23.9	28.00	unacceptable

The fact that two of the "adjusted" analyses in Table 5.14 are still unacceptable implies that the relationship between O/C and depth or H/C and depth are not neccessarily given by equations (3) and (4).

Fig. 5.35 Calorific Value (daf) versus depth (cm) for Valley Mire peats



5.2.5.3 Calorific Value

There is a weak tendency for CV to increase with depth, especially in the case of Rikasrus and Goergap (Fig. 5.35). This is to be expected as calorific value is positively related to fixed carbon (see Fig. 5.37). However, in some cases a large discrepancy exists between the inferred value and the determined value, eg. in the case of sample GMB X2 @ 100cm, the inferred calorific value based on the formula, CV = 0.34 FC + 0.18 VM, is 8.2 MJ/kg. The measured value is 3 MJ/kg (Appendix 2, Fig. 5.37). This discrepancy of 5.2 MJ/kg suggests a high percentage of incombustible volatiles.

$CV_{volatile} = CV_{total} - CV_{FC}$

$= 3 - 1.2$

$= 1.8$ MJ/kg

If it is assumed that the combustible volatiles are mainly represented by methane (CH_4, equivalent to 75% C and 25% H, with a CV of 75 * 0.34 +25 *1.162 = 54.6 MJ/kg)then the volatiles in this sample consist of only about 3.3% methane and 39.1 - 3.3 = 35.8 CO_2 and H_2O. This implies a carbonate content of the peat of up to about 80 per cent. the inferred value is therefore unreliable in the case of carbonate rich peat.

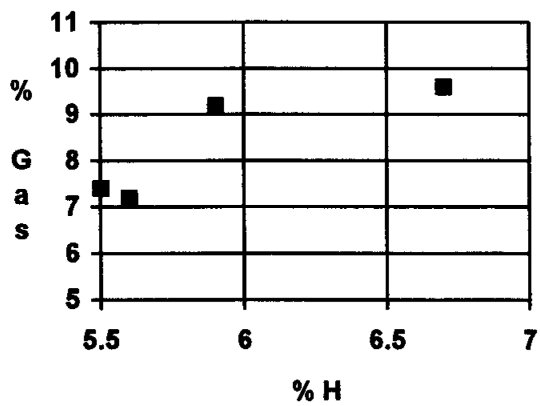
5.2.5.4 Fischer Assay. (Table 5.15; Fig.5.37)

Wood fragments isolated from the lower levels of a sedge/reed mire (GMB/X3 @ 50cm; 26°29'S;27°08'E) demonstrate a low coke and high gas content with high tar contents. Since the tar content is primarily dependent on the hydrogen content one would expect this to be reflected in hydrogen analyses, as indeed it seems to do; it also appears as if gas has a similar positive correlation with hydrogen (ignoring the apparently erroneous values obtained for GMB X3 @ 50cm) (Fig. 5.36). It has also been pointed out that the ultimate analysis of RIK @ 100cm appears to be wrong (Appendix 3; Table 5.15).

TABLE 5.15 FISCHER ASSAYS (daf) AND ELEMENTAL CHARACTERISTICS (daf) OF SOME SELECTED PEATS

SAMPLE	COKE %	TAR %	WATER %	GAS %	% H	% C	% O
TP2 @ 140cm	68.8	8.4	15.6	7.2	5.6	61.1	30.7
RIK @ 100cm	62.8	8.0	19.6	9.6	6.7	66.4	24.3
RIK @ 150cm	73.4	4.6	14.6	7.4	5.5	58.2	33.1
GMB/X3 @50cm	45.8	11.3	0.9	42.0	6.1	59.7	31.0
GMB/X1 @ 60cm	65.2	4.8	20.8	9.2	5.9	60.3	29.8

Fig. 5.36 Possible relationships between the hydrogen contents of peat and the corresponding gas and tar yields of the Fischer assay.



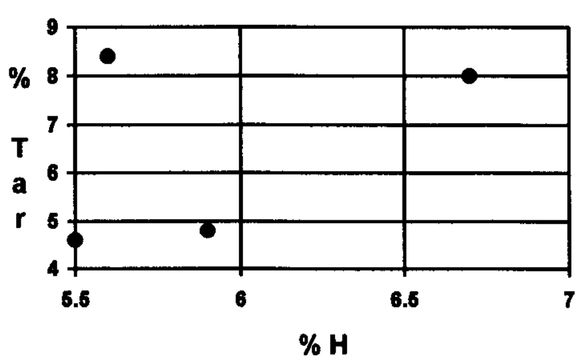
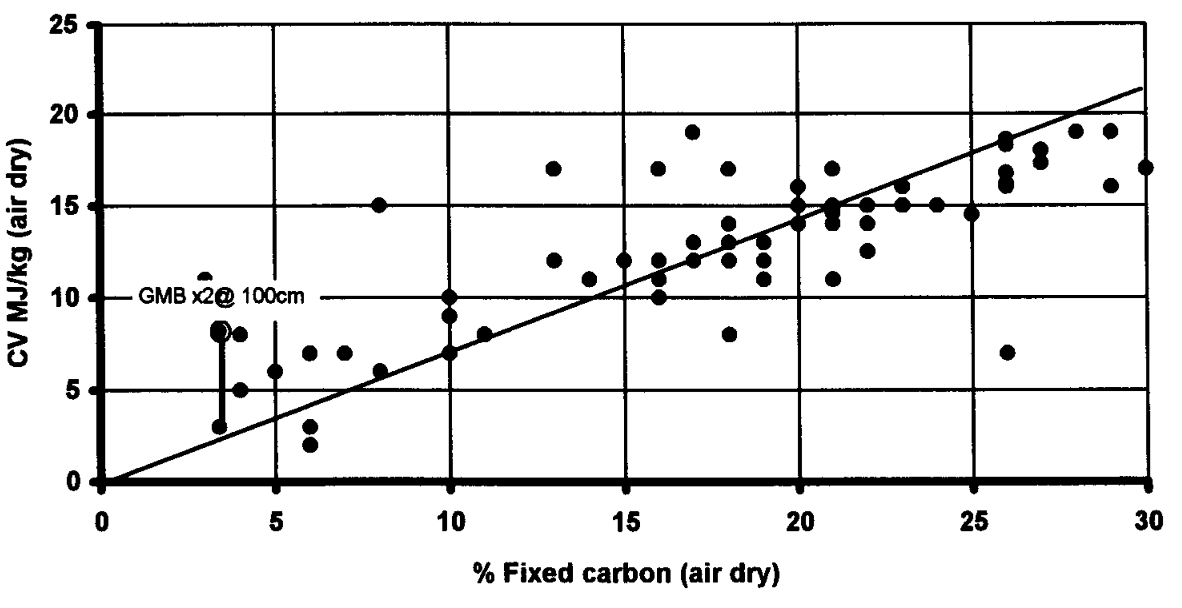


Fig. 5.37 Calorific value versus Fixed carbon for valley mire peats. (The circled value is calculated from CV = 0.34 FC + 0.18 VM, and is joined with a tie-line to the corresponding determined value).



5.2.6 Mineral matter

5.2.6.1 Mineralogical composition.

(Table 5.16). Inland valley mire peats exhibit a predominance of quartz (81%) with subordinate amounts of kaolinite (9%). Gypsum, calcite and pyrite (1%) were also present in some peats.

TABLE 5.16 AVERAGE COMPOSITION (%) OF THE MINERAL MATTER IN INLAND VALLEY MIRE PEATS. (X-ray diffraction analysis).

MINERAL	REED/SEDGE n = 7	Range
Quartz	81	84 - 100
Kaolinite	9	2 - 15
Gypsum	0.5	0 - 3
Calcite	1	0 - 3
Pyrite	1	0 - 8

5.2.6.2 Sulphur content.

The average and ranges for total sulphur for inland valley mire peats are listed in Table 5.17. Note that Northern Transvaal peats have the lowest average sulphur content, approximately half that found in Western Cape peats. This low sulphur content (particularly near surface) may be an indication of the greater distance of the Northern Transvaal mires from industrial centres with high pollution levels.

TABLE 5.17 AVERAGE SULPHUR CONTENTS FOR VALLEY MIRE PEATS

Peat type	n	average %	range
S/E Transvaal	5	0.15	0.01 - 0.65
N Transvaal	4	0.12	0.01 - 0.35
PWV area	8	0.15	0.03 - 0.58
Western Cape	9	0.23	0.03 - 0.75

5.2.6.3 Ash Analyses

The average trace and major element concentrations in ash of Valley Mire peats are given in Tables 5.18 and 5.19. In Fig. 5.38 and 5.39 the average concentrations in the ash of different peat types are compared in terms of percentage deviation from the mean of all Valley Mire samples. Transvaal peats are relatively enriched in all major elements with respect to the mean; Cape peats are impoverished in Fe_2O_3, Al_2O_3, MnO and K_2O whilst enriched in MgO, Na_2O and especially CaO; and Natal peats are enriched in Al_2O_3, Fe_2O_3, MnO, MgO, S and poor in CaO and Na_2O (Fig. 5.38). Transvaal peats are enriched in all traces except Y, Zn and Zr, all trace elements are close to the mean, whereas Cape peat is poor in all trace elements except for Mo, Nb, Th, U, Y, Zn and Zr relative to the average. The values of the Natal peats are close to the mean or slightly lower for the trace elements listed (Fig. 5.39).

Similar major element correlations and interrelationhips with trace elements as described in NMC peats are observable in the valley mire peats, eg the chalcophile elements Zn, Cu and Ni show a positive correlation (Fig. 5.40 a and b), suggesting that these elements occur in sulphide minerals; Ba and Rb are strongly correlated, suggesting that they are accomodated in potassium feldspar or in illite (formed from potassium feldspar ?) (Fig. 5.40 c). The Cr/Zr ratios of Transvaal peats seem to show a trend opposite to that of the Cape peats (Fig. 5.40 d), probably reflecting the presence of larger outcrop areas of basic and ultrabasic rocks which could act as a source of chromium in the Transvaal peats. Cape peats also show a poor correlation between CaO and Al_2O_3, sugesting that calcium-rich plagioclase (or its alteration products) is not an important clastic mineral in these peats, in contrast with Natal and Transvaal peats.

Trace elements can also be a useful tool to determine the state of a mire with respect to pollution. Table 5.18 lists the average trace element contents for Transvaal and Western Cape valley mire peats together with a set of analyses from the Klip River mire. Note that most of the trace elements (with the exception of Rb and Zr) in the top one metre of the Klip River mire at locality KL3/2 are unusually high. Anomalous values can be defined as those above the mean + 2 standard deviations, and strongly anomalous values as above the mean + 3 standard deviations. Of special interest are the strongly anomalous values (with respect to Transvaal peat for Cu, Ni, Pb and Zn) in the top sample at location KL 3/2. The Zn is also strongly anomalous in the bottom sample, and even about 1 km down-stream from KL 3/2, whereas the strong Cu anomaly in the top of KL 3/2 also becomes less pronounced down-stream. The Ni/Zn ratios in the clay base ($105/67 \cong 1.6$) is similar to that of the mean ($120/82 \cong 1.5$), hence it can be assumed that the anomalous values must be ascribed to an external source.

It seems likely that the KL 3/2 samples were taken near a site were industrial waste is dumped. However the rapid decrease in concentration of the heavy metals must be ascribed to the filtration and absorbtion effect of the peat. Other trace elements may simply reflect the geology of a particular area, for example, the Western Cape peats have higher Zr-contents which probably point to the proximity of the various Cape granites, while higher Cr-contents in the Transvaal peats point to the presence of basic rocks in the provenance of the ash-forming elements.

TABLE 5.18 SELECTED TRACE ELEMENTS FROM VALLEY MIRE PEATS. Anomalous values in KL (Klip River Mire) with respect to Transvaal peat are indicated by shading.)

Element	Transvaal (n=18)	Standard Deviation	W Cape (n=5)	Standard Deviation	KL Clay base	KL 3/2 bottom	KL 3/2 top	KL 2 down stream
Ba	363	201	207	91	440	266	681	481
Cr	332	179	181	137	376	312	461	436
Cu	67	41	31	9	89	127	219	171
Ni	120	248	39	46	105	231	1606	265
Pb	25	6	15	2	24	15	63	24
Rb	63	36	35	11	91	89	87	86
Sr	65	46	162	176	52	64	109	75
Zn	82	11	104	3	67	134	1784	122
Zr	233	93	435	75	277	238	210	241

TABLE 5.19 MAJOR ELEMENT ANALYSES FOR VALLEY MIRE PEATS.

	Cape	SD	Transvaal	SD	Natal	SD
SiO_2	89.4	3.8	76.5	6.8	70.0	12.3
TiO_2	0.8	1.1	0.9	0.2	0.8	0.2
Al_2O_3	4.2	2.0	14.4	2.7	17.8	6.9
Fe_2O_3	1.6	1.5	4.0	1.5	0.2	0.2
MnO	0.0	0.0	0.0	0.0	8.5	7.0
MgO	0.7	0.4	0.3	0.2	0.0	0.0
CaO	2.8	3.4	0.8	0.3	0.3	0.0
Na_2O	0.2	0.2	0.1	0.0	0.4	0.2
K_2O	0.3	0.3	0.8	0.8	0.1	0.0
P_2O_5	0.2	0.0	0.2	0.1	0.6	0.2
S	0.2	0.2	0.1	0.1	0.3	0.1

Fig. 5.38 Deviation from the mean for major elements in Valley Mire peats

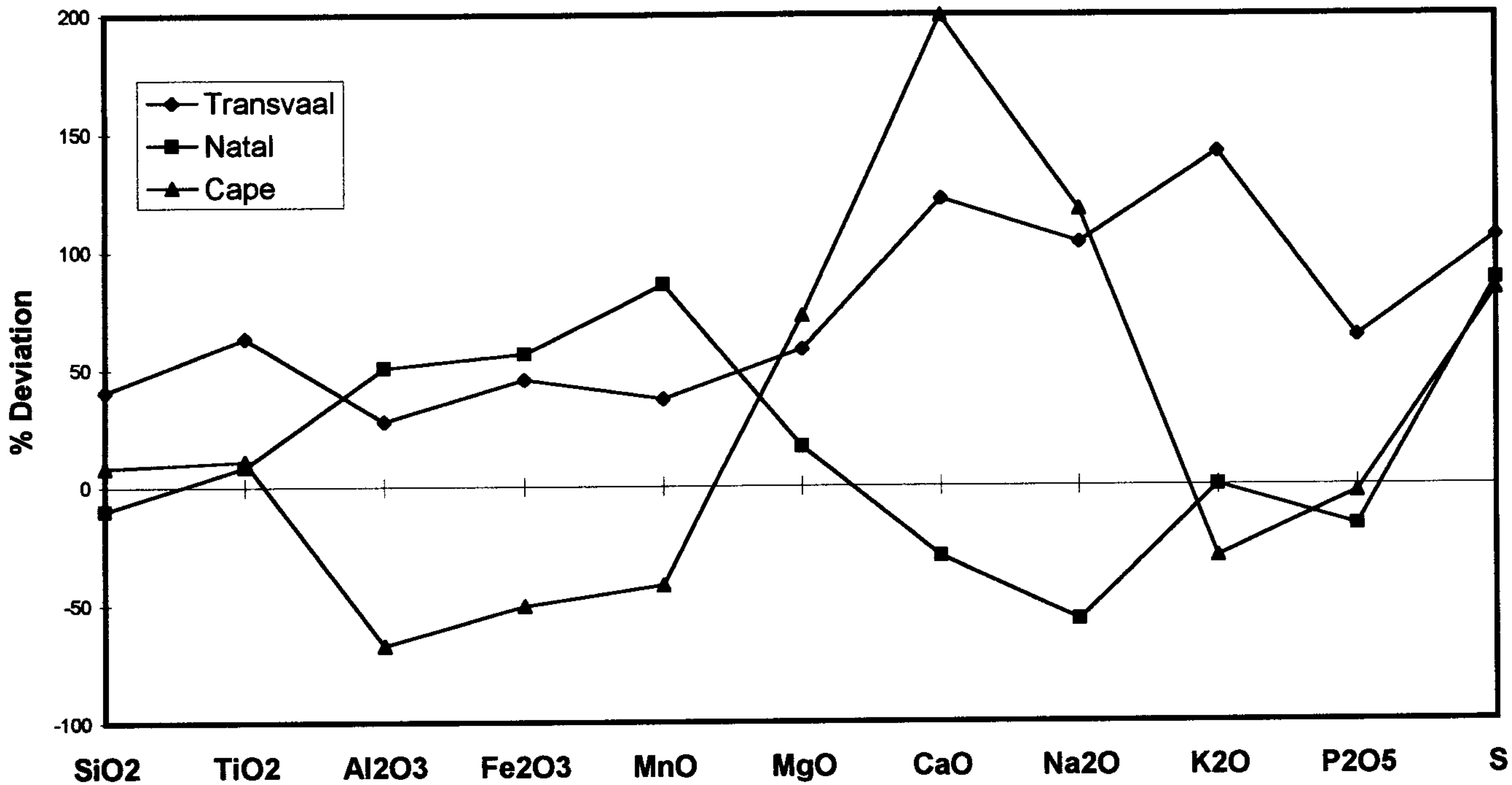


Fig. 5.39 Deviation from the mean for trace elements in the Valley Mire peats

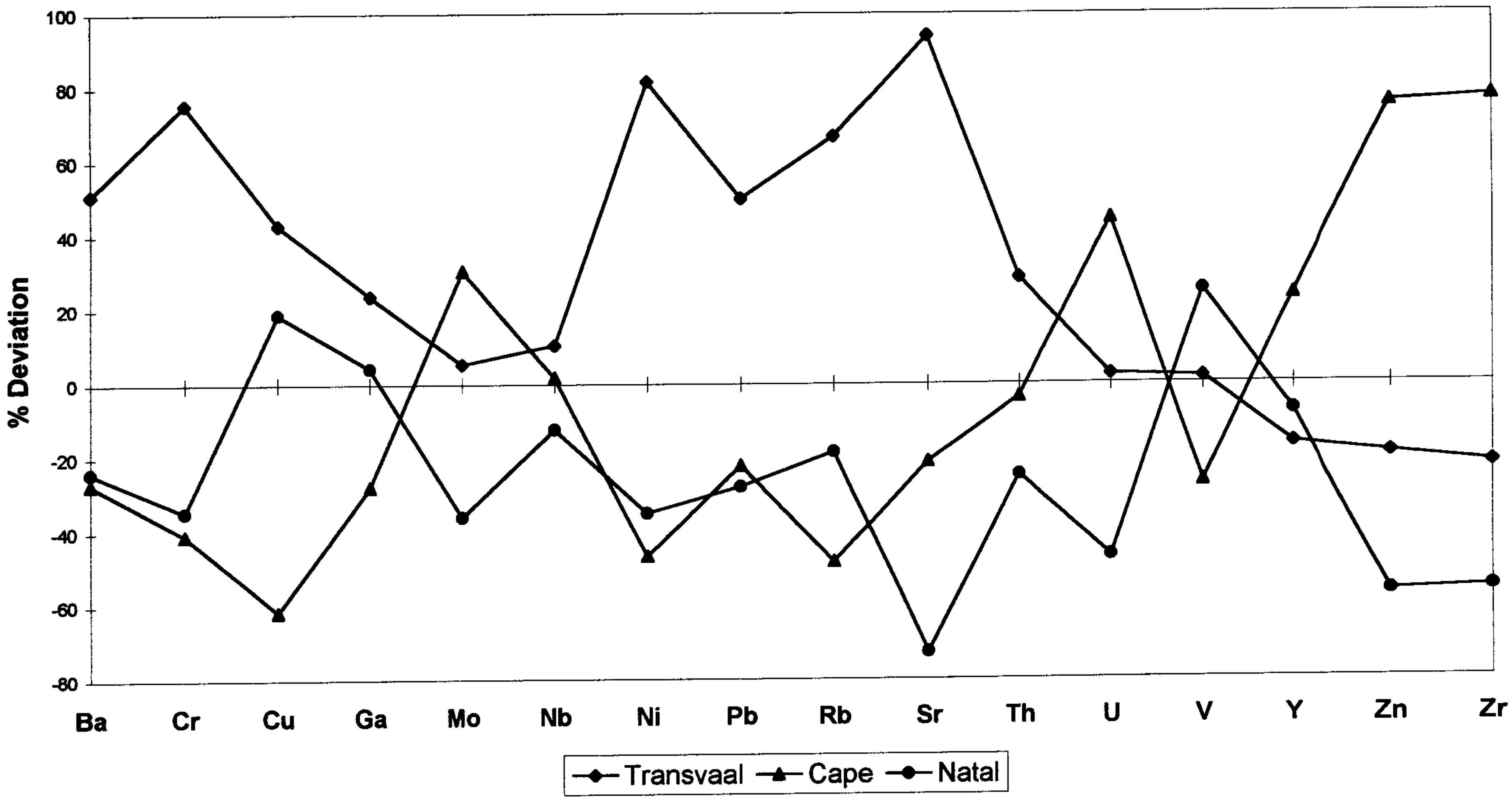
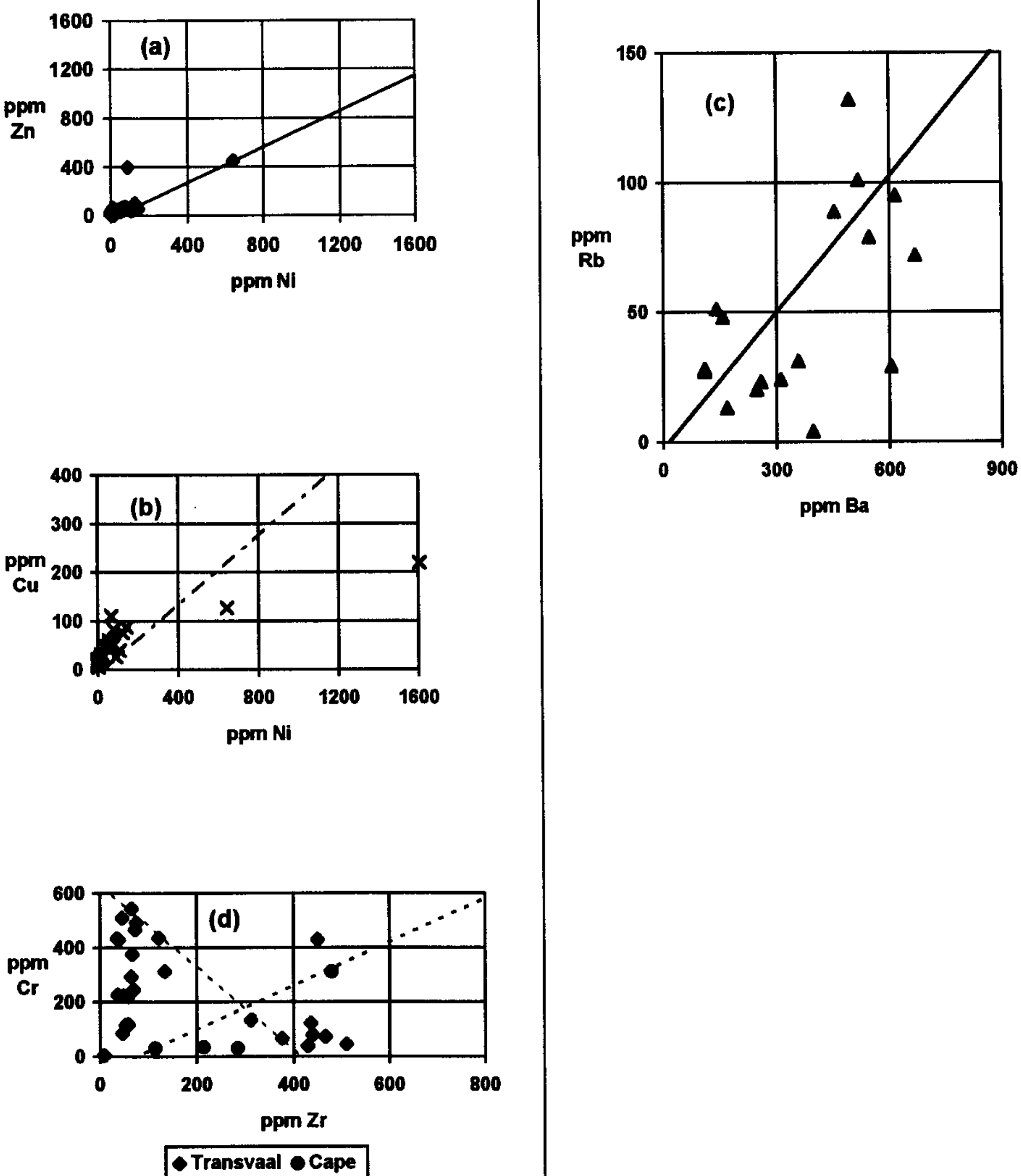


Fig. 5.40 Trace element relationships observed in peat ash analyses



5.2.7 Conditions of peat formation.

Although a fair number of peat radiocarbon dates are reported for southern Africa in the literature (Scott and Vogel, 1983; Scott and Thackeray, 1987; Meadows, 1988) they have never been used in an attempt to quantify peat accumulation rates (Table 5.20, Table 5.21). Throughout southern Africa there were certain time intervals during which organic deposition was likely to be initiated or accelerated; these were ± 15 000 BP, 13 000 to 10 000 BP, 8 000 to 7 000 BP, 6 000 to 3 000 BP and 2 000 BP to the present (Meadows, 1988). The peats investigated generally find their origins in one of these intervals.

TABLE 5.20 RADIOCARBON DATES FOR SOME VALLEY MIRE PEATS (determined by EMATech, CSIR).

CSIR number.	Sample name/depth	^{14}C age (yrs BP)	LOCALITY
Pta-6369	Witdraai 58 cm (RIK)	1050 +- 50	26°12'30 S;27°33'30"E
Pta-6363	Witdraai 87 cm (RIK)	2580 +- 60	26°12'30 S;27°33'30"E
Pta-6367	Gerhard Minnebron 550 cm (GMB)	11310 +- 110	26°29'40"S;27°8'E

Sample Pta-6363 was taken from the base of an ash layer within the peat profile. This ash layer can be found over hundreds of kilometres in different mires at similar depths and is assumed to represent a regional feld fire that occurred after an extended period of regional drought. Only a major drought during which a significant volume of peat was dried out will explain an ash layer in excess of 30 cm. This age correlates well with the lowest "frequency of onset of organic deposition" (i.e. most likely dry, warmer conditions) for the last 5 000 years BP according to Meadows (1988). There is also a good correlation between the age of the onset of peat formation in samples Pta-6369 and Pta-6367 and the respective periods listed by Meadows (op. cit.).

TABLE 5.21 RATES OF PEAT ACCUMULATION IN TRANSVAAL REED/SEDGE MIRES (mm.yr^{-1}).

	interval years	interval thickness (cm)	cumulative	with 35% compaction
11310 - 0 BP	11310	550	0.49	0.75
11310 - 2580 BP	8730	463	0.53	0.82
1050 - 0 BP	1050	58	0.55	0.85

5.3 Inland Extensive Mires

In southern Africa with its relatively dry and warm climate extensive mires outside the wetter eastern coastal belt are very scarce. When they do occur it is because of very specific facilitating factors that exercise a regional impact on a system in order to advance mire formation. A prime example of such a situation can be found in the Okavango Swamp Complex in northern Botswana (Fig. 4.6). The delta is closely linked with, and controlled by NE/SW striking faults and the associated half graben (Hutchins et al., 1976; Cairncross et al., 1988; McCarthy et al., 1989a; 1989b; McCarthy and Ellery, 1993).

5.3.1 Geomorphological setting

The delta, a classical birds-foot configuration, is about 18 000 km² in extent and forms part of the internal drainage of the intracratonic Kalahari Basin (McCarthy et al., 1989). The panhandle and delta (all areas susceptible to flooding between the Xoro and Thamalakane faults) have a gradient of 1:7130, dropping 62 m in 442 km (Smith, 1976). The delta is divided into three parts: the narrow upper panhandle, the central perennial swamp were flow is confined between vegetated peat banks, and the seasonal swamps where peat is absent (Smith, 1976; McCarthy et al., 1989b).

5.3.2 Vegetation

Smith (1976) recognises five important plant communities in the perennial swamp: *Cyperus papyrus* in deeper water, *Miscanthidium* in shallow-flooded sites, *Phragmites australis, Typha latifolia* var. *capensis* and *Pycreus* spp.. The latter three occur under various hydrological conditions between those ideal for *Cyperus* and *Miscanthidium* respectively. All five these plant communities are generally efficient biomass generators and peat formers (Thompson, 1976), and they appear to be acting accordingly in the Okavango Delta (McCarthy et al. 1989).

5.3.3 Field Characteristics of the peat

In the perennial swamp where *Cyperus papyrus* is typically the major plant type, open water channels can be in the order of 20m wide confined by peat beds of up to 3m thick. Dense living vegetation and peat form the edges of the channels cause perching of the water level in the channels (McCarthy et al. 1988). This results in slow water flow away from the channels through the vegetation and underlying peat. The peat becomes more compact with depth, typically exhibiting a reddish colouring. Detrital quartz sand and silt with kaolinite form the most important inorganic components and occur throughout the peat profile (McCarthy et al., op cit.). Vigorous papyrus growth (leading to the development of extensive peat swamps) are associated with the development of new channels in the delta. As channels mature aggradation of both the channel bed and peat swamp occurs, reducing the gradient to such a point where the vegetation begins to block the channel, leaving it moribund (Cairncross et al., 1988). Flow switched to a new channel, leaving the old one to desiccate and finally burn out. These fires are seen as a normal part of the channel evolutionary cycle in the delta. Cairncross et al. (1988) estimate this aggradational increment to last about 100 years and found the maximum peat aggradation to be about 4m during this phase. The effect of the fire was to reduce the thickness of the accumulated peat to less than 0.5m, representing the net aggradation on the delta surface associated with a single cycle of channel evolution.

5.3.4 Physical-chemical properties and mineral matter

The chemical analyses of both the peat forming plants and the resultant peats that were studied by McCarthy et al. (1989) are listed in Tables 5.22; 5.23 and 5.24. Note that except for *Cyperus papyrus* roots and rhizomes, all other plant parts exhibit relatively high ash contents (Table 5.22). Calorific values for the peat forming plants and the peat were calculated using Boie's formula. Assuming that the mean O/C ratio of the original plant material was 1.11, the degree of decomposition is higher in the middle reach than in the upper reach of the Okavango Swamp, viz.

100 (1.11 - 0.93) / 1.11 = 16.2%, and

100 (1.11 - 1.06) / 1.11 = 4.5% respectively,

with an average for all the analysed peats of 8.1% (see Table 5.23). No analyses were available from the lower reach.

The general tendency of the plant and peat mass to filter out the inorganics from the water that flows into the swamp can clearly be seen in the decrease in ash content from 61.7% (upper reach), to 30.8% (middle reach), to 14.3% (lower reach). The peat also becomes increasingly depleted downstream in certain major elements, especially iron, sodium and potassium (McCarthy et al., 1989). The positive or negative trends in he inter-oxide relationships in the ash of the peat in the upper, middle and lower reaches of the Okavango Swamp are summarised in Table 5.24. Some of these trends are illustrated in Fig. 5.41. The positive trends between Al_2O_3 on the one hand and CaO, K_2O and TiO_2 on the other suggest that these elements are mainly accomodated in smectitic and/or illitic clay minerals; the negative trend between Fe_2O_3 and TiO_2 indicates that heavy iron and titanium minerals (ilmenite, rutile, etc.) are not important constituents of the mineral matter in he peat. The strong positive relations between CaO, Fe_2O_3 and MgO, especially in the lower reaches, suggest that most of the iron and also calcium and magnesium are accomodated in carbonate minerals, eg. calcite, ankerite and/or siderite.

Figure 5.41 Significant major element relationships in the three parts of the Okavango Swamp

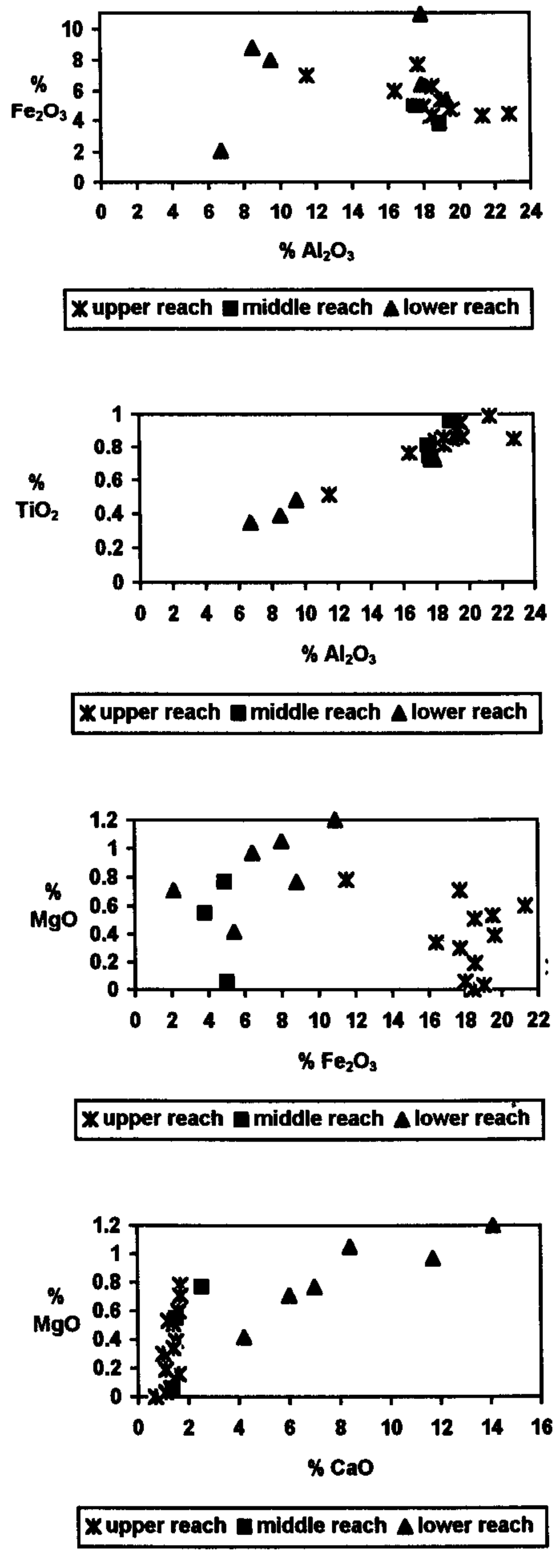


Table 5.22 Analysis of plant material (dry basis) (after McCarthy et al., 1989, Table 1)

	PL2	PL3	PL1	PL8	PL6	PL5	PL4
C	-	40.44	41.66	39.77	41.73	42.38	40.56
H	-	5.50	5.32	4.78	5.18	5.20	5.15
O*	-	43.76	44.72	52.75	47.04	45.70	40.17
N	-	1.06	0.63	0.75	0.93	0.78	1.52
Ash	12.28	9.24	7.67	1.95	5.12	5.94	12.60
Ash composition							
SiO_2	81.48	83.84	74.20	63.10	75.18	43.04	66.51
TiO_2	0.25	0.01	0.01	0.18	0.02	0.31	0.05
Al_2O_3	3.02	0.14	0.32	1.89	0.62	2.89	0.20
Fe_2O_3	3.69	0.12	0.09	1.31	0.19	2.30	0.18
MnO	0.60	0.26	0.35	1.23	0.38	2.86	0.25
MgO	1.54	1.75	2.23	2.71	1.88	7.07	4.83
CaO	3.01	3.21	5.96	4.72	4.01	11.96	13.50
Na_2O	0.44	0.42	7.59	3.45	3.22	O.S0	0.25
K_2O	3.56	6.64	6.67	17.11	10.41	23.41	10.50
P_2O_5	0.25	0.94	0.60	1.66	0.76	1.44	0.97
Total	97.84	97.33	98.01	97.38	96.33	95.79	97.22
O/C	-	1.06	1.07	1.33	1.13	1.08	0.99
H/C	-	0.14	0.13	0.12	0.12	0.12	0.13
CV **	-	15.3	15.4	13.3	15.0	15.4	15.4

PL2: *M. junceum* roots and rhizomes; PL3: *M. junceum* leaves;

PLI: *C.papyrus* stems; PL8: *C. papyrus* roots & rhizomes;

PL6: *C.papyrus* umbel; PL5: *T. interrupta* roots

PL4: *T. interrupta* leaves * oxygen by difference

** Calorific Value (MJ/kg dry) according to Boie's formula.

Table 5.23 Chemical Analysis of Peat Samples (from McCarthy et al., 1989, Table 3)

Upper Reach														
	EL11	EL12	EL13	EL20	EL21	EL22	FK17	EL18	EL19	G72	G73	G90	E9****	Mean	S.d.
C	-	-	-	-	-	-	16.52	-	-	12.16	9.98	18.84	13.11	14.12	
H	-	-	-	-	-	-	2.44		-	2.08	1.83	2.04	1.74	2.03	0.27
O*	-	-	-	-	-	-	16.13	-	-	12.49	12.29	17.59	15.64	14.74	2.41
N	-	-	-	-	-	-	1.19	-	-	1.00	0.77	1.48	1.07	1.10	0.26
Ash	73.83	50.67	51.37	68.08	62.17	58.88	63.72	46.13	51.45	72.27	75.13	60.05	68.44	61.71	9.64
O/C	-	-	-	-	-	-	0.98	-	-	1.03	1.23	0.93	1.19	1.07	
H/C	-	-	-	-	-	-	0.15	-	-	0.17	0.18	0.11	0.13	0.15	
CV calc							6.7	-	-	5.2	4.2	6.9	4.8	5.6	
Ash Composition															
SiO2	74.40	70.49	67.78	73.02	70.72	70.83	69.59	72.04	73.39	72.60	70.97	75.64	68.71	71.55	2.25
TiO2	0.85	0.86	0.85	0.80	0.85	0.81	0.99	0.84	0.76	0.86	0.95	0.51	0.72	0.82	1.12
Al2O3	18.41	19.62	22.85	17.72	19.02	18.45	21.34	18.11	16.35	18.47	19.45	11.51	17.73	18.39	2.65
Fe2O3	4.31	4.80	4.44	4.96	5.44	6.29	4.29	4.98	5.95	4.29	4.66	7.03	7.73	5.32	1.12
MnO	0.04	0.04	0.03	0.05	0.08	1.14	0.05	0.04	0.13	0.10	0.06	0.26	0.18	0.09	0.07
MgO	0.00	0.39	0.16	0.30	0.03	0.19	0.60	0.06	0.34	0.51	0.53	0.78	0.71	0.35	0.26
CaO	0.70	1.48	1.56	1.00	1.05	1.14	1.56	1.26	1.36	1.36	1.19	1.72	1.67	1.31	0.29
Na2O	0.10	0.11	0.04	0.11	0.13	0.16	0.15	0.07	0.13	0.08	0.07	0.07	0.29	0.12	0.06
K2O	1.04	1.05	0.93	1.02	1.07	1.08	1.21	1.00	1.14	0.98	1.06	1.13	1.71	1.07	0.08
P2O5	0.13	0.23	0.22	0.19	0.20	0.25	0.12	0.32	0.25	0.12	0.10	0.35	0.35	0.22	0.09
TOTAL	99.98	99.04	98.90	99.16	98.57	99.33	99.91	98.72	99.51	99.37	99.04	98.99	99.26		
Quartz	17.5	-	4.8	-	-	-	14.4	6.3	7.7	13.3	13.9	4.9	6.0	9.9	4.9

* By difference

Middle Reach						Lower Reach								
	FK16	EL17	FK18	Mean**	S.d		EL1	EL9	EL23	K26	K9	K41	Mean	S.d
C	17.28	-	28.06				-	-	-					
H	2.40	-	3.50				-	-	-					
O*	16.42	-	25.20				-	-	-					
N	1.10	-	1.42				-	-	-					
Ash	62.80	55.90	41.82	30.82	18.43		14.72	11.47	27.86	11.76	6.34	13.53	14.28	7.25
O/C	0.95	-	0.90				-	-	-	-	-	-	-	-
H/C	0.14	-	0.12				-	-	-	-	-	-	-	-
CV calc	6.9		10.9											
Ash composition														
SiO2	71.54	73.41	70.41	69.82	4.01		51.67	59.07	66.81	82.28	68.53	71.64	66.65	10.52
TiO2	0.96	0.81	0.74	0.80	0.17		0.72	0.73	0.88	0.35	0.48	0.39	0.59	0.21
Al2O3	18.98	17.49	17.57	17.11	3.18		17.89	17.91	19.31	6.74	9.50	8.51	13.31	5.64
Fe2O3	3.83	5.00	4.92	5.78	1.67		10.93	6.43	5.44	2.07	8.03	8.81	6.95	3.06
MnO	0.04	0.08	0.08	0.01	0.04		0.16	0.05	0.09	0.02	0.35	0.29	0.16	0.13
MgO	0.55	0.06	0.77	0.84	0.32		1.20	0.97	0.42	0.71	1.05	0.77	0.85	0.28
CaO	1.51	1.39	2.54	3.84	2.12		14.06	11.67	4.17	5.99	8.38	7.02	8.55	3.69
Na2O	0.16	0.10	0.33	0.19	0.07		0.07	0.11	0.10	0.17	n.d.	0.12	0.11	0.04
K2O	1.21	1.05	1.46	1.17	0.17		0.92	0.98	1.04	0.58	0.83	0.68	0.84	0.18
P2O5	0.09	0.25	0.39	0.39	0.20		1.18	1.21	0.59	0.80	1.87	0.90	1.09	0.45
TOTAL	98.87	99.63	99.22				98.79	99.12	98.85	99.71	99.01	99.02		
Quartz	18.6	6.9	4.5	5.7	5.05		1.4	1.4	-	-	-	-	1.4	-

* Oxygen by difference, ** Mean includes data from Table 4 in McCarthy et al. (1989), **** Sludge sample.

Table 5.24 Inter-oxide trends: peat ash Okavango Swamp (based on data from McCarthy et al., 1989).

Oxide pair	*Upper Reach*	*Middle Reach*	*Lower Reach*
Al_2O_3 - Fe_2O_3	- (s)	- (w)	none
Al_2O_3 - CaO	+ (w)	+ (w)	+ (w)
Al_2O_3 - K_2O	none	none	+ (s)
Al_2O_3 - TiO_2	+ (s)	+ (s)	+ (s)
CaO - Fe_2O_3	+ (w)	+ (s)	+ (s)
CaO - MgO	+ (w)	+ (w)	+ (s)
Fe_2O_3 - TiO_2	- (s)	- (s)	- (s)

Note: S = strong, W = weak.

♦♦♦♦♦

6 PROPERTY INTERRELATIONSHIPS OF SOUTH AFRICAN PEATS

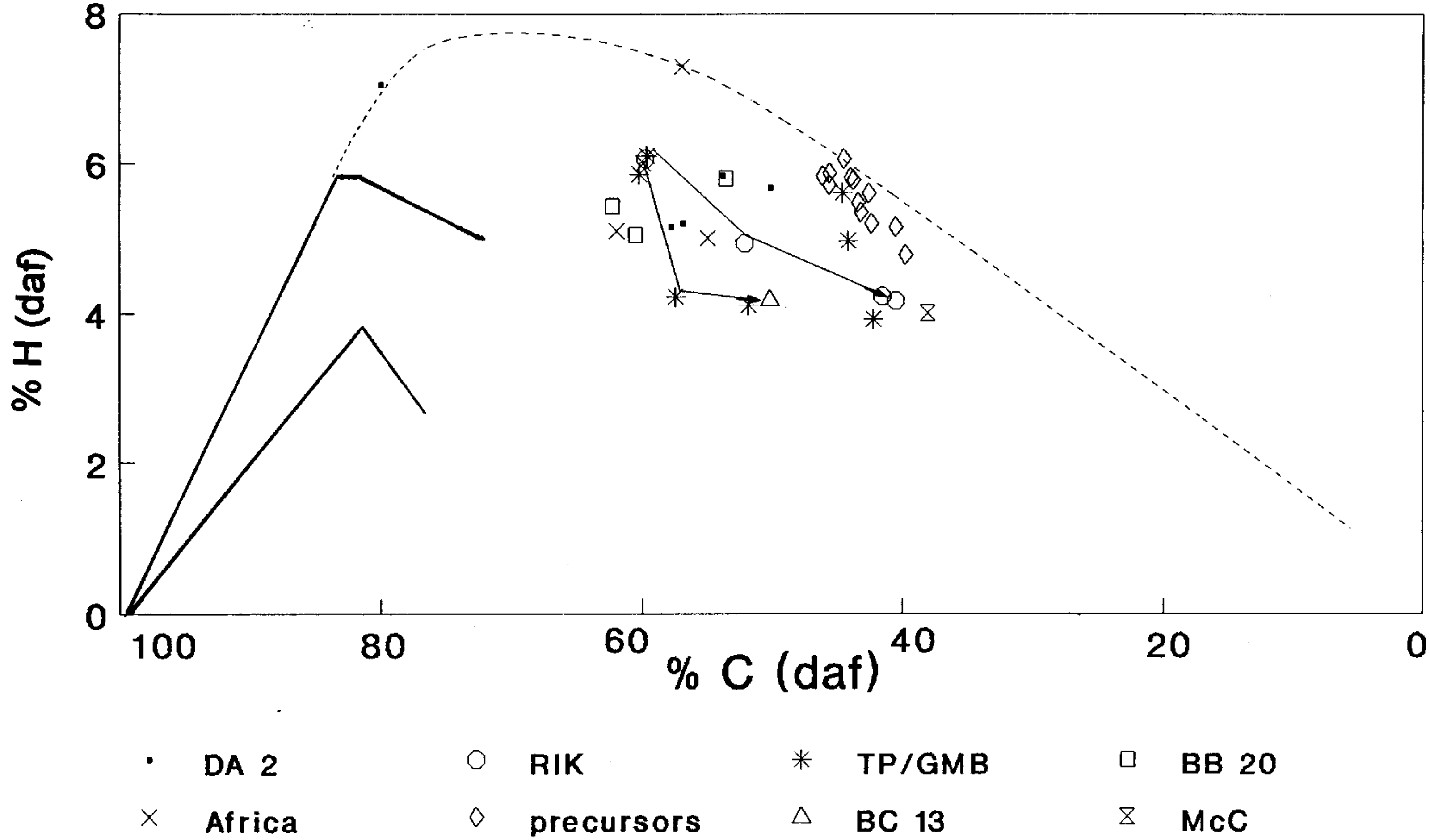
6.1 Carbon - hydrogen

Six typical southern African peats, three peats from West Africa (Chateauneuf *et al.*, 1991) and a number of peat forming plants were compared on a modified Seyler diagram (Fig. 6.1). The relevant peats were:

- (2732 DA 2) NMC forest peat
- (RIK) Rikasrus
- (GMB) Gerhard Minnebron, valley mire sedge/reed peat
- (2732 BB 20)- (27°07'S;32°49'E) Black Rock
- (2732 BC 20)- (27°22'30"S; 32°37'30"E) NMC sedge/reed Sibayi
- (precursors) typical peat forming plants from the Okavango Swamp (Table 5.22)
- (McC) Okavango peat (Table 5.23) (McCarthy *et al.*, 1989).

These peats, as well as the peat precursors, do not fall on the extension of the South African coal band, but are clearly more hydrogen rich for a particular carbon content. South African peats are in this respect no different from the other African peats also shown in figure 6.1.
The depth of burial (ie. age) of the peats appears to be one of the factors affecting its position on the Seyler chart. The two African samples with the highest H-contents (6% daf) were taken near surface (0.20 - 0.80 m) in Rwanda and Burundi and yielded ages of 1145 ± 130 BP and 900 ± 180 BP respectively (Chateauneuf *et al.*, 1991) . This appears to correlate well with RIK and TP/GMB samples from similar age/depth horizons in South African valley mires (0.58 m; 1050 ± 50 BP). Similarly the older peats from Senegal (1.2 m; 5500 ± 100 BP - Chateauneuf *et al.*, 1986 and Chateauneuf *et al.* 1988) plot close to older South African sedge/reed peats. From this it appears that sedge/reed peat is subject to a decrease in both hydrogen and carbon with depth apparently due to demethanation. However in

Fig. 6.1 Seyler diagram for some South African peats and peat precursors



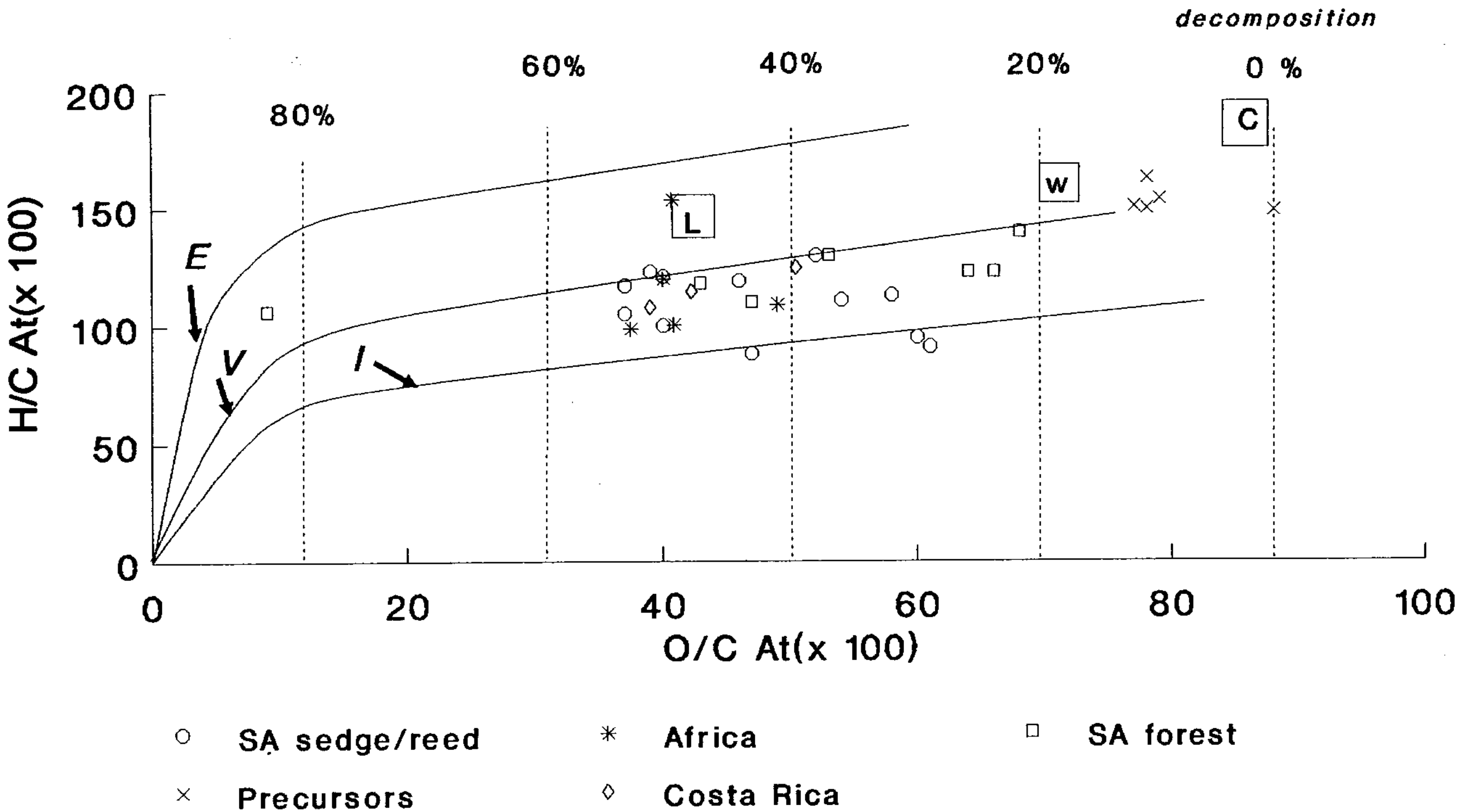
Band for South African Coal (Snyman etal., 1983, Barnard, 1987)

This Study

Tie-line joining peat with increasing depth in the direction of the arrow.

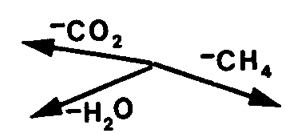
The analysis showing the high carbon content is obviously unreliable (see appendix 3 and 5.1.5.2)

Fig. 6.2 South African peats with some other examples in relation to the Van Krevelen "coal band"



(E)xinite (V)itrinite (I)nertinite (W)ood, (C)ellulose, (L)ignin

African values (Chateauneuf et al. 1991)
Costa Rica (Cohen et al 1985)
Precursors (McCarthy et al. 1989a) sedge/reed plants



some other sedge/reed peats the opposite was found, or that hydrogen increased at the expense of carbon due to a loss in oxygen (by dehydroxylation) or in carbon (decarboxylation) respectively.

6.2 H/C - O/C (atomic proportions)

With the aid of Van Krevelen's "coal band" (Van Krevelen, 1961) South African forest peat was compared with sedge/reed peat and peats from Costa Rica (Cohen *et al.,* 1985), West and Central Africa (Chateauneuf *et al.,* 1991), sedge/reed plants (McCarthy *et al.* 1989a) and wood, lignin and cellulose (Van Krevelen & Schuyer, 1957) (Fig. 6.2).

Shown on an inset of the diagram are the directions of demethanation, dehydration and decarboxylation. The first point observed is that all the peat samples, bar one, fall in the decomposition range of 20 % to 60 %. One wood peat sample plots at + 80 % decomposition and we are most likely dealing here with a much older lignitious fragment. All peats predominantly plot between two maceral development lines, with forest peat somewhat inclined towards the vitrinite line and sedge/reed peats towards the inertinite line. This fact is also shown by the maceral analyses carried out on the two types of peat (Fig. 5.11; 5.31).

The forest peats range in composition from close to wood (composed essentially of cellulose and lignin) to near lignin, pointing to increasing decomposition of the less resistant cellulose as coalification progresses.

Starting from fresh peat forming plants (Fig. 6.2) (no decomposition) it is noticeable that the primary reaction is dehydration, accompanied by decarboxylation as the plants are being peatified. Demethanation is of subordinate importance in the peat stage (cf. Van Krevelen and Schuyer, 1957, p 96-100).

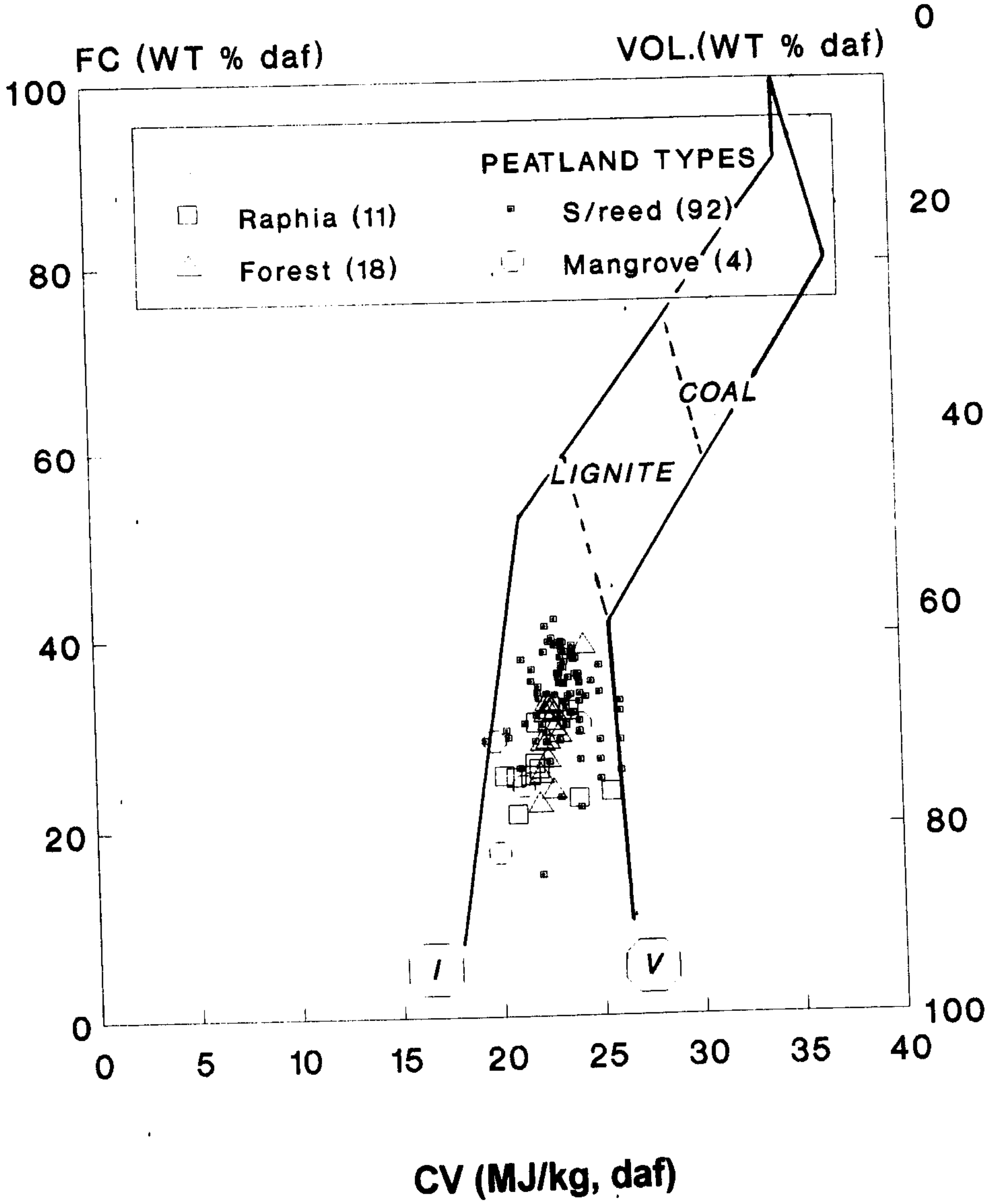
6.3 Fixed carbon / volatile matter versus calorific value

A diagram of fixed carbon and volatile matter plotted against calorific value (all values recalculated dry ash free) indicates that all South African peats fall within the "normal" coal band, spread between the inertinite and vitrinite precursor lines. The upper fixed carbon limit for South African peats thus appear to be at about 59 % (daf) and the calorific value limit about 26 MJ/kg (daf) (Fig. 6.3).

The major NMC peat fields (and average point for each peat type) are shown in relation to the extended coal band in Figure 6.4. Note that both mangrove and raphia peats exhibit narrow (CV ranges), elongated (fixed carbon) fields while forest and sedge/reed peats both have wide ranging fields. Mangrove peats are highly inertinitic, raphia and forest peats plot between inertinite and vitrinite and sedge/reed peats tend to lean over towards the vitrinite precursors.

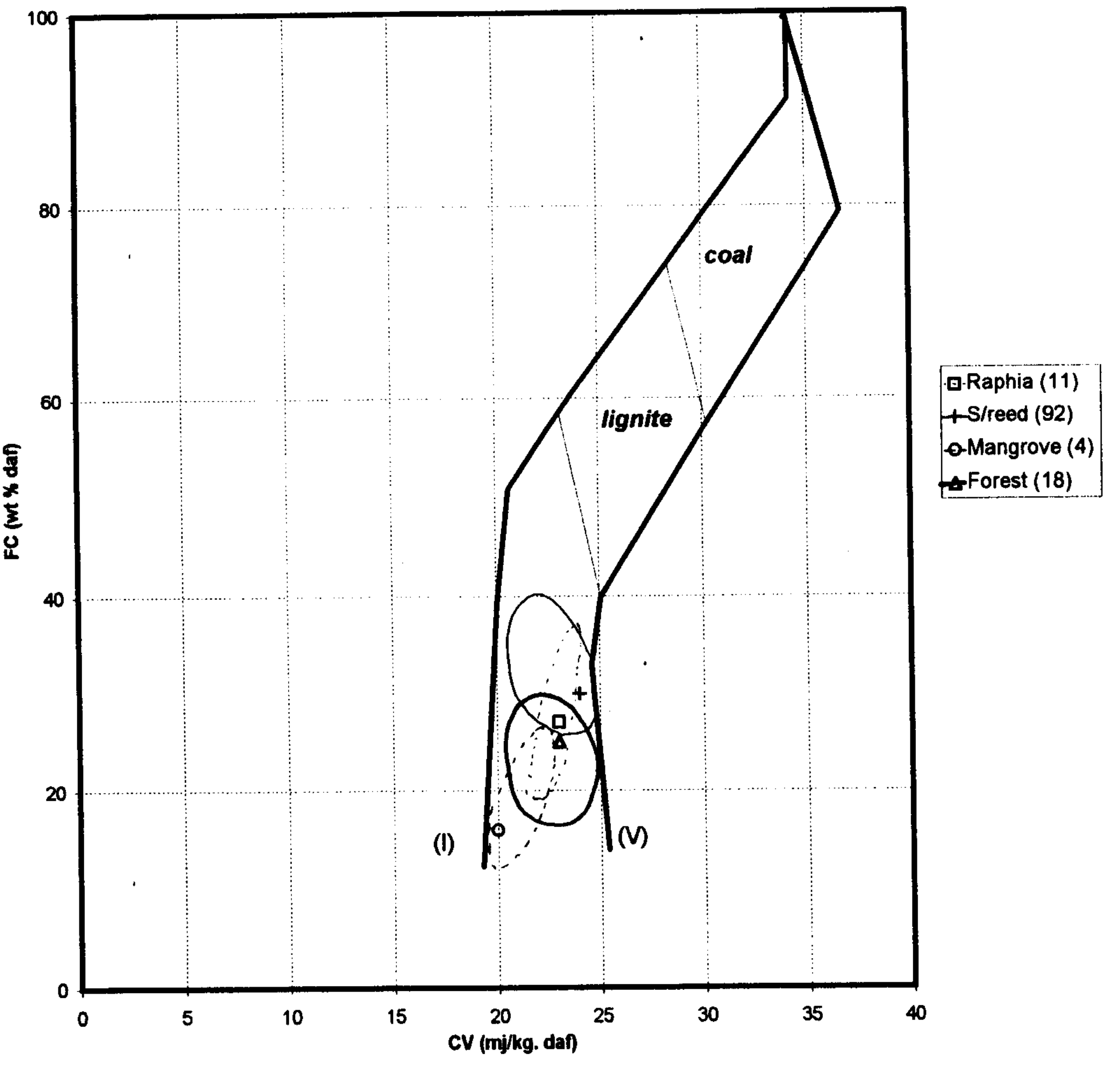
Valley mire peats (also largely sedge/reed) when compared against NMC sedge/reed peats indicate on average lower calorific values but slightly higher fixed carbon contents (Fig. 6.5). The valley mire peats are all more inertinitic, with the lowest CV/FC peats nearest to the inertinite line. The reason for the more inertinitic nature of the valley mire peats is most likely to be found in their climatic situation which is conducive to more regular fires and oxidation during cyclic dry periods.

Fig. 6.3 FC (daf) versus CV (daf) with respect to the coal band



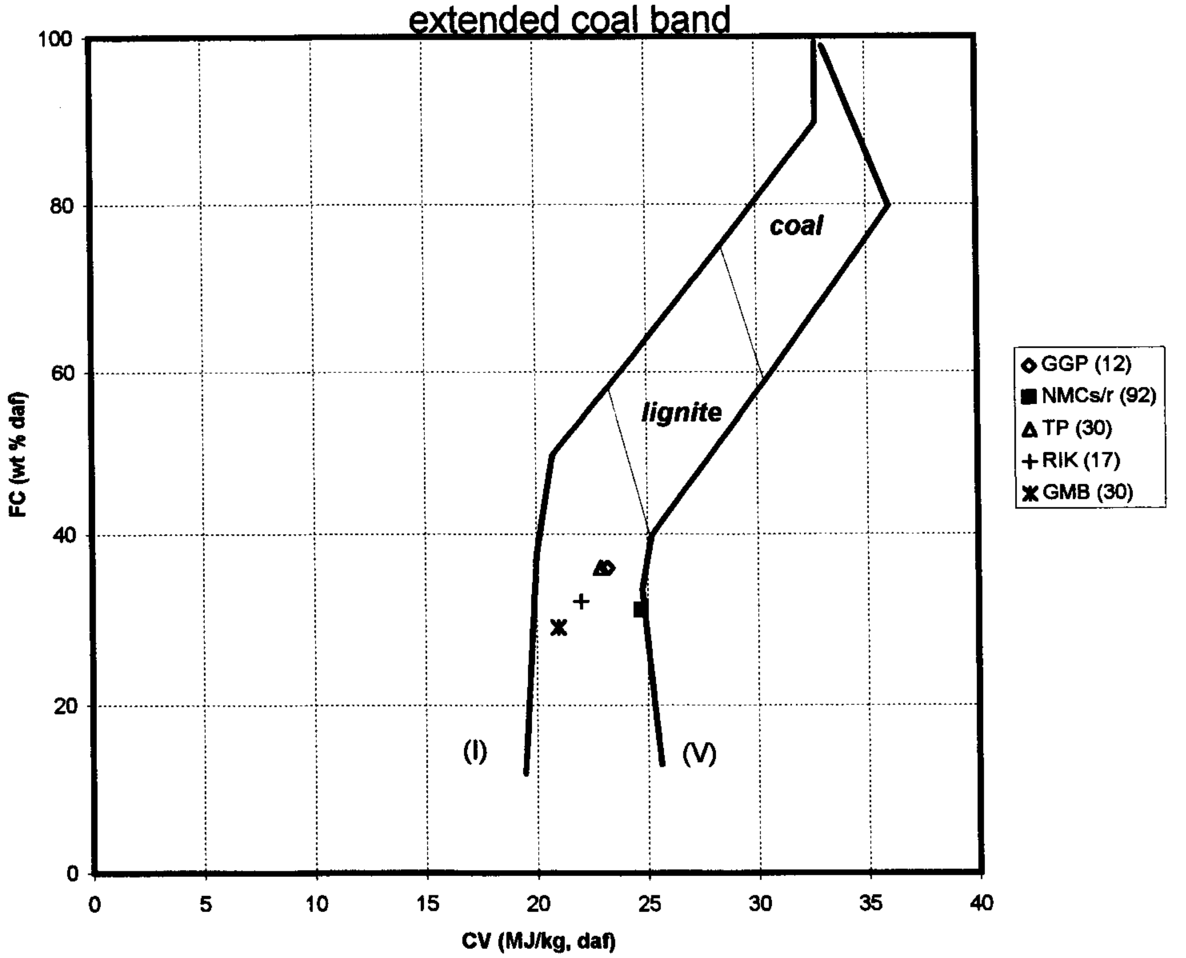
(I)nertinite precursors
(V)itrinite precursors

Fig. 6.4 Major peat fields with respect to the coal band



(I)nertinite precursors
(V)itrinite precursors

Fig. 6.5 Valley mire and NMC s/r peat in relation to the extended coal band



(I)nertinite prrecursors (V)itrinite precursors (s/r) sedge/reed
TP - Tarlton; RIK - Rikasrus; GMB - Gerhard Minnebron; GGP - Goergap

6.4 Composition of volatile matter

The composition of the volatile matter is given by the difference between total carbon and fixed carbon plus the hydrogen, oxygen, nitrogen and sulphur contents. Volatile matter for three peat types was compared in terms of their H/C and O/C atomic ratios in order to determine whether there is any difference in composition (Fig. 6.6).

NMC sedge/reed peat have H/C : O/C ratios in excess of 2:1; forest peats ratios of generally more than 1.5:1 (but with a fairly wide spread) and valley mire peats ratios of generally more than 1.2:1.

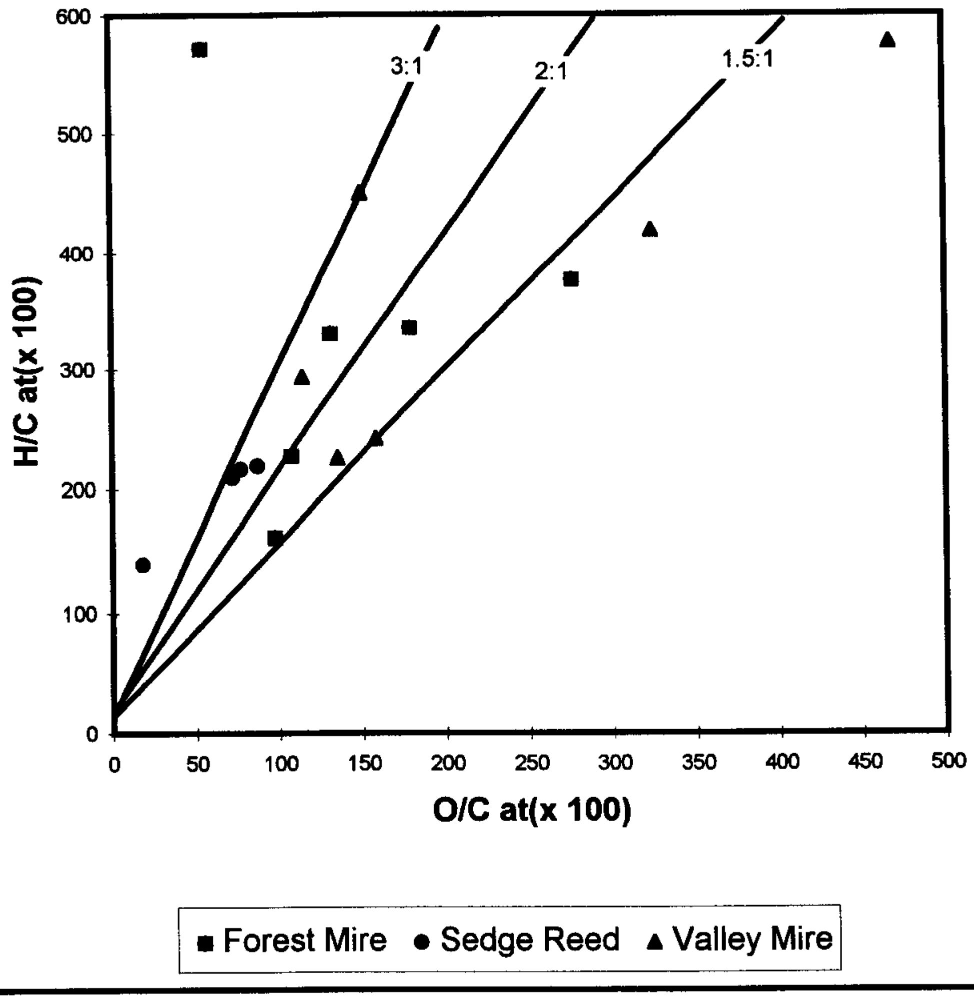
6.5 Fischer assay.

Transvaal sedge/reed peats (valley mire) have higher coke (67.5%) and tar (6.5%) yields than NMC sedge/reed peats (52% and 4.4% respectively), while water (17.7%) and gas (8.3%) yields of Transvaal peats are lower than those of NMC peats respectively (23.2%) and (20.4%).

Peat woods (Mgobozeleni and Sibayi, Appendix 3) demonstrate low coke and high gas yields with medium to high tar yields. Transvaal sedge/reed peats appear to present a distinctly high tar (8.2%) and low tar (4.7%) grouping. Since tar content is primarily dependent on the hydrogen content one would expect this to be reflected in hydrogen contents.

Inspection of the ultimate analysis of these peats indeed points this out where low-tar peat has H-contents of 2.8% to 4.4% and high-tar peats have H-contents of 3.2% to 4.7%.

Fig. 6.6 The H/C vs O/C ratios of the volatile matter of South African peats



7 A COMPARISON WITH OTHER PEATS IN AFRICA

In this chapter I will attempt a brief comparison of South African peats with other African peats, both from the literature and from my own experiences with peats from the Congo, Benin and Mozambique.

7.1 Proximate analysis

The average air-dry moisture content of all the peats under consideration is about 9%. NMC forest peat has the highest average value of about 12% and the Congolese sedge/reed peats the lowest of about 6% (Fig. 7.1). The low moisture content of Benin marsh and Congo sedge/reed (from Mbamou island, Congo River) peats is due to the high average ash contents in excess of 50%. Similarly a high ash content has a lowering effect on the fixed carbon and volatile matter contents.

7.2 Fixed carbon/volatile matter versus calorific value

Both Benin and Congo sedge/reed peats plot as expected with South African sedge/reed peat. Papyrus peat (coastal zone) and fern peat (Mbamou Island) from the Congo both have surprisingly high fixed carbon contents (Fig. 7.2). When all data for Congo papyrus peats were placed on the diagram it was found that they plot into two distinct groups, one with the sedge/reed samples and the other with Mbamou Island fern peat samples. Closer inspection of the papyrus peats then revealed that they indeed consist of layers of pure papyrus remains interlayered with horizons rich in fern remains.

7.3 Petrography

South African sedge/reed peats are much richer in inertinite (largely fusinite) than any other African peat listed (Fig. 7.3).

SA forest peat exhibits a maceral content very similar to that of Togo peat which appears to be much alike in terms of peat forming plants and broad environmental conditions (Fig. 7.3) (Chateauneuf *et al.*, 1991).

7.4 Inorganic fraction

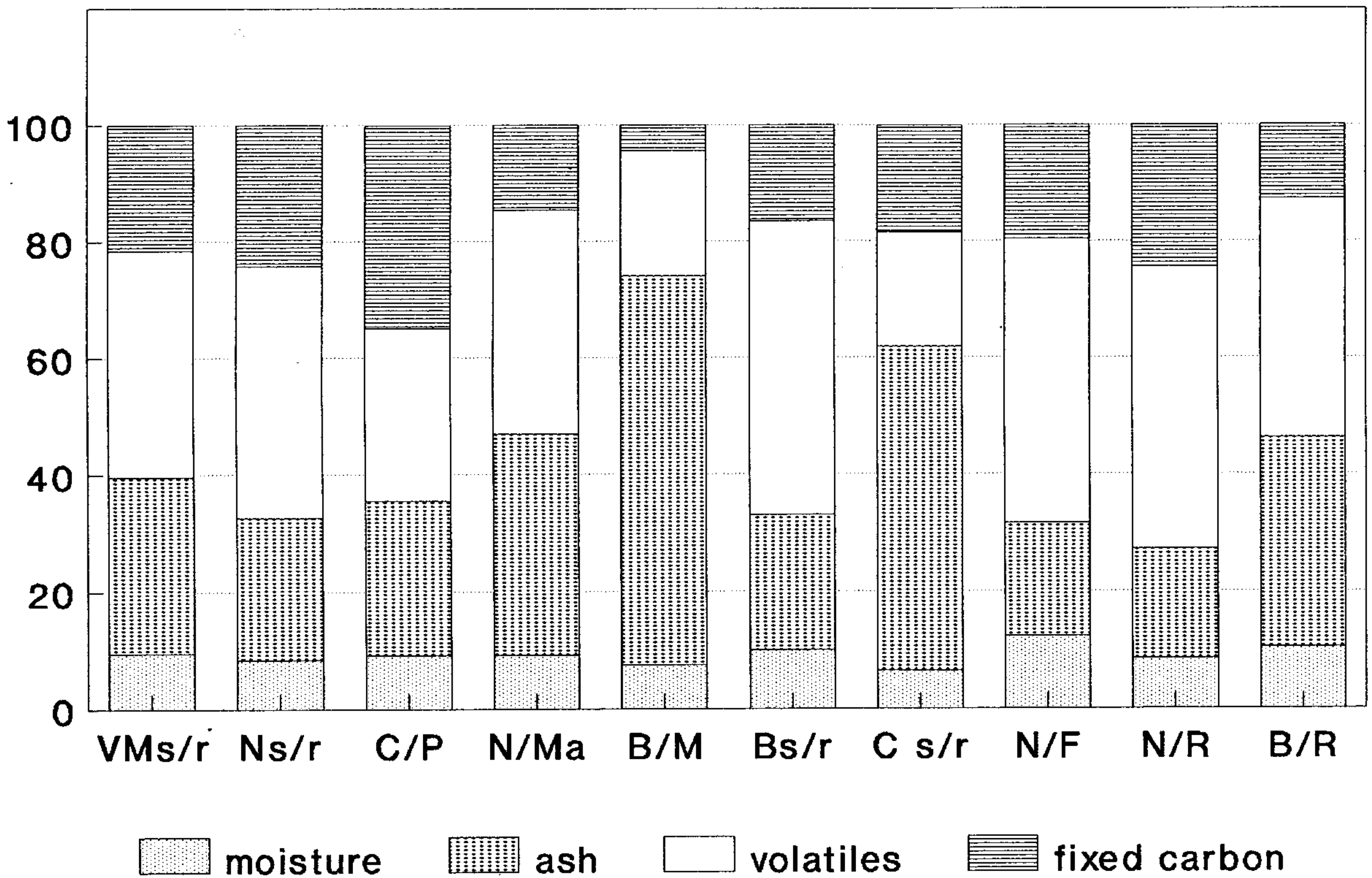
The nature of the geological substratum and the immediate surrounds of a mire generally play a major role in supplying the inorganic fraction to the peat. The grade of the peat is largely determined by allogenic mineral matter washed into the mires (Table 7.1).

TABLE 7.1 Mean ash analysis (calculated to 100 %) and clay mineral composition of the inorganic fraction

	Main oxide fractions (% of total ash content)							Clay Minerals* (on a scale of 0 to 10)		
	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	K	I	I/S
Tvl s/r	67.0	16.0	7.6	2.3	6.0	0.3	0.8	10	0	0
Cp s/r	86.2	6.7	3.2	0.7	2.3	0.4	0.5	0	0	0
NMC s/r	94.0	2.7	1.7	0.3	0.6	0.1	0.7	10	0	0
Forest	94.0	2.4	1.1	0.5	1.4	0.1	0.4	0	8	2
Raphia	89.7	3.7	3.3	0.3	2.2	0.1	0.7	3.3	0	6.7
Mangrove	69.0	17.3	9.5	1.2	1.4	0.4	1.2	0.8	0.2	9
Senegal	41.0	25.0	22.0	6.0	3.6	3.7	0.7	7	3	0
Togo	51.7	26.0	14.5	5.0	1.5	0.5	0.8	0.5	2.5	7
Rwanda	79.0	14.0	3.3	2.0	0.6	0.3	0.8	9.5	0.5	0
Burundi	69.7	20.0	7.5	0.7	0.8	0.8	0.5	10	0	0
mean	74.1	13.4	7.4	1.9	2.0	0.6	0.7	5.1	1.4	2.5
S	±17	±9	±6	2.0	1.7	1.1	0.2			

* K = Kaolinite, I = Illite, I/S = interstratified Illite/Smectite, relative concentrations.

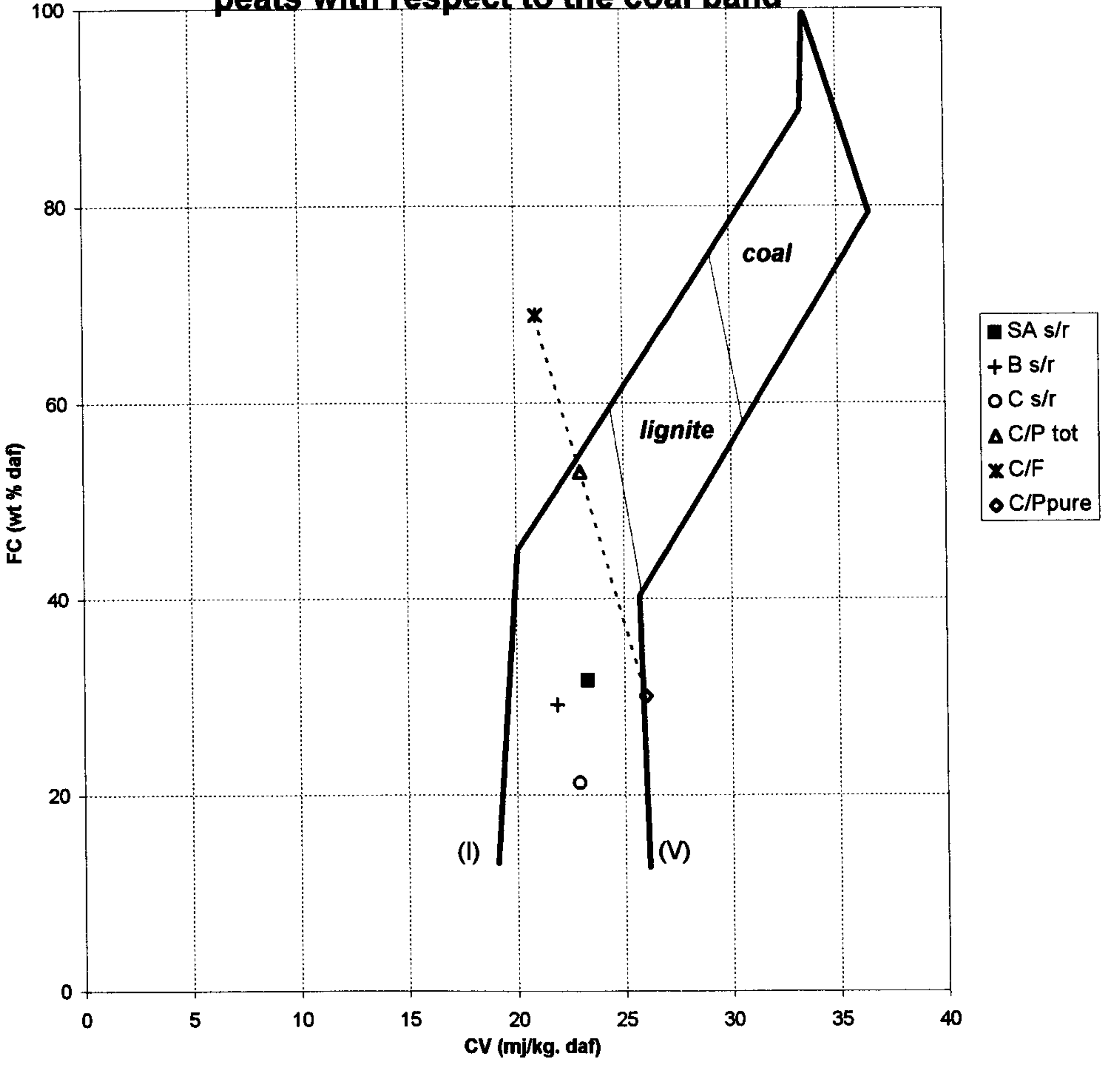
Fig. 7.1 Proximate analyses of SA peats compared to some other African examples



(N)MC, (VM) Valley mire, (C)ongo, (B)enin

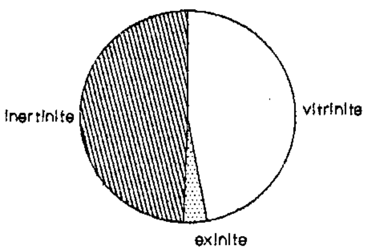
(R)aphia, (Ma)ngrove, (M)arsh, (F)orest, (P)apyrus, (s/r) sedge/reed

Fig. 7.2 South African peats compared to other African peats with respect to the coal band

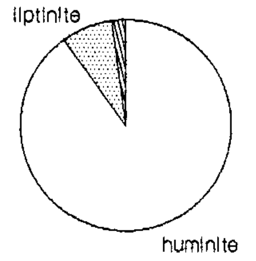


SAs/r - South African s/r; Bs/r - Benin s/r; Cs/r - Congo s/r; C/Ptot - Congo papyrus, total peat; C/F - Congo fern peat; C/Ppure - Congo pure papyrus peat

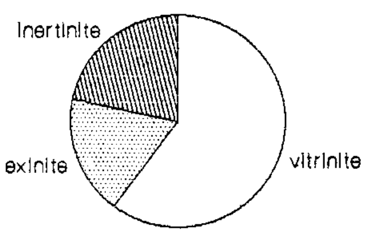
Fig. 7.3 Maceral Composition from South Africa, West Africa and Central Africa



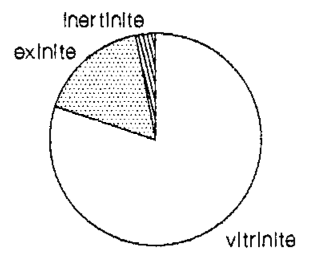
SA sedge/reed



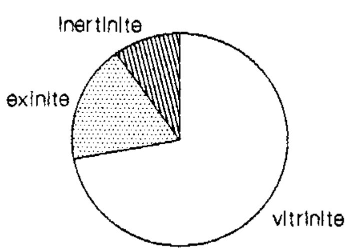
SA Forest



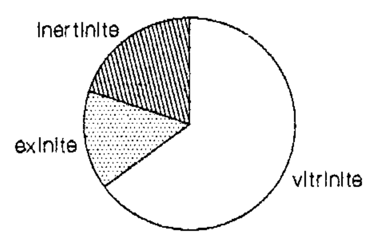
SENEGAL *



TOGO *



RWANDA *



BURUNDI *

* *Chateauneuf et al. (1991)*

Transvaal sedge/reed peats are closest to Rwanda and Burundi peats in terms of their mineral matter composition and clay mineral contents (Table 7.1). NMC peats (excluding mangrove peat) have very high silica contents with very low aluminium and iron contents compared to those of Senegal. Both the Natal Mire Complex and the Niayes of Senegal occur within older coastal dunes immediately behind the present dune systems and one would expect very similar mineral fractions. Chateauneuf *et al.* (1991) cite the filtering effect of the Guinean vegetation surrounding the Senegal mires for the abnormally low silica content as well as the fact that most of the mire water is supplied from groundwater uplift. The high percentage of iron (22%) is ascribed to leaching from ferralitic soils. NMC sedge/reed and Senegal peats both have low clay contents which consist mainly of kaolinite derived from pedological horizons surrounding the mires. NMC forest peats have some horizons rich in illite and illite/smectite clays. Raphia peats (kaolinite and illite/smectite - small quantities) and mangrove peats (K, I, I/S - abundant) are both dominated by interstratified illite/smectite clays comparable to Togo. The following trends, as defined by a difference by more than one standard deviation from the mean, were observed;

SiO_2: >91% NMC s/r, forest
<57% Senegal, Togo
Al_2O_3: >22% Senegal, Togo
<13% NMC s/r, forest, raphia
Fe_2O_3: >13% Senegal, Togo
<1.4% NMC forest
MgO: >3.9% Senegal, Togo
CaO: >3.7% Tvl s/r
Na_2O: >1.7% Senegal
K_2O: >0.9% mangrove
<0.5% forest

From this one can infer positive correlations between Al_2O_3 - Fe_2O_3 - MgO and a negative correlation between Al_2O_3 - SiO_2.

7.5 Accumulation and growth rates.

Some radiocarbon dates for peats are available from Senegal, Burundi, Congo and Benin. Age versus depth for South African peats are compared with these African examples in figure 7.4. The rates for Sibayi and Mgobezeleni (Table 5.13) are the same, as is the case with the two Transvaal peatlands (Table 5.21). However, the rate for the two Transvaal peatlands is much lower than that for the NMC (Fig. 7.4).

The rate of peat formation in the Transvaal is comparable to the rates for the Congo and Senegal while the NMC rate compares well to the rates for Benin and Burundi. Inspection of the data from Burundi suggests the following relationship between the age (a) and the depth (d in cm) of the relevant peat:

$$d = 1.6218\ a^{0.79}$$

$$\text{i.e. } \log d = 0.21 + 0.79 \log a \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The ages calculated on the basis of the peat depth are compared with determined ages in Table 7.2 below:

TABLE 7.2 Calculated ages compared with measured ages for Burundi peats

d = depth (cm)	age calculated	age determined*	% difference
484	1357	1 430	-5.1
1 005	3 423	3 070	+11.5
1 489	5 629	5 700	-1.2
2 011	8 236	8 650	-4.8
3 277	15 282	20 200	-24.3

* (Pajunen, 1985)

Equation (1) can be used to infer the compaction of the peat by calculating the change in peat depth over succesive 10 year periods, eg.

after the first year ; $\log d = 0.21 + 0.79 \log 1$

$$\therefore d = 1.62 \text{ cm}$$

after the tenth year; $\log d = 0.21 + 0.79 \log 10$

$$\therefore d = 10 \text{ cm}$$

The change in depth is equal to the change in thickness, viz 8.38 cm, and this thickness is assumed to be that of the uncompacted peat , i.e. 100% thickness. Subsequent changes in thickness are expressed as a percentage of 8.38 cm (Table 7.3). The results of these calculations are shown in Fig. 7.5. Based on the compaction data in Table 7.3 the growth rates of the peat, calculated from determined thickness and determined age (Table 7.2), are listed in Table 7.4.

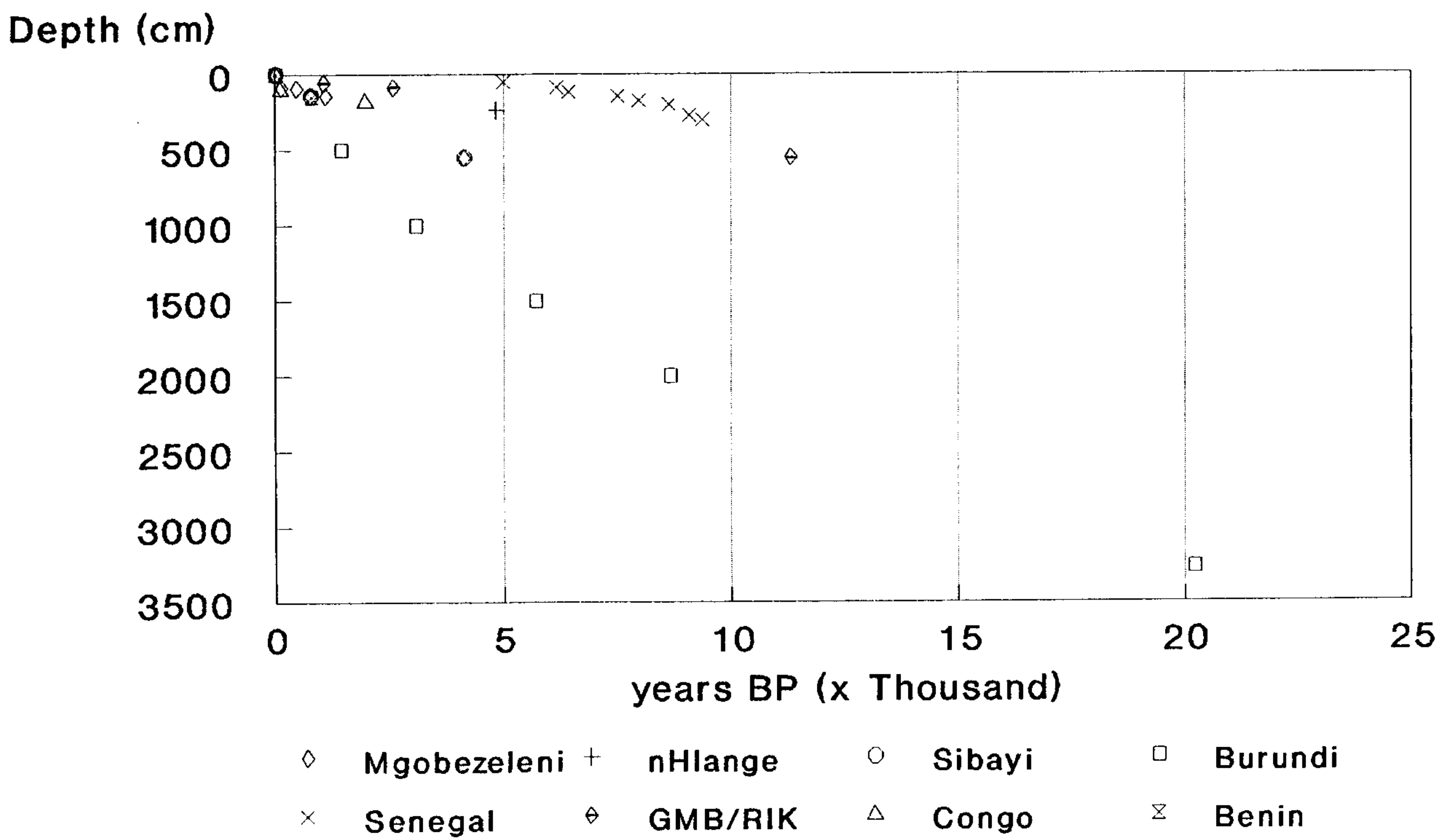
TABLE 7.3 Percentage change in thickness with depth calculated from Equation (1): $d = 1.6218 \cdot a^{0.79}$, d_1 = thickness after first year and d_{10} = thickness after tenth year of a ten year period.

year	d_1 (cm)	years	d_{10} (cm)	change	%
1	1.62	10	10	8.38	100.00
11	10.78	20	17.29	6.51	77.68
21	17.97	30	23.82	5.85	69.81
31	24.44	40	29.90	5.46	65.16
41	30.49	50	35.66	5.17	61.69
51	36.22	60	41.19	4.97	59.31
61	41.73	70	46.52	4.79	57.16
71	47.04	80	51.69	4.65	55.49
81	52.20	90	56.74	4.54	54.18
91	57.23	100	61.66	4.43	52.86
201	107.03	210	110.80	3.77	44.99
301	147.25	310	150.72	3.47	41.41
401	184.71	410	187.97	3.26	38.90
501	220.23	510	233.35	3.12	37.23
1001	380.49	1010	383.19	2.70	32.22
* 1421	501.82	1430	504.33	2.51	29.95
2001	657.64	2010	659.97	2.33	27.80
3001	905.82	3010	907.96	2.14	25.54
* 3061	920.09	3070	922.23	2.14	25.54
4001	1136.88	4010	1138.90	2.02	24.11
5001	1355.99	5010	1357.91	1.92	22.91
* 5691	1501.75	5700	1503.63	1.88	22.44
* 8641	2088.75	8650	2090.46	1.71	20.46
* 20191	4083.90	20200	4085.33	1.43	17.11

TABLE 7.4 Growth rate of peat from Burundi

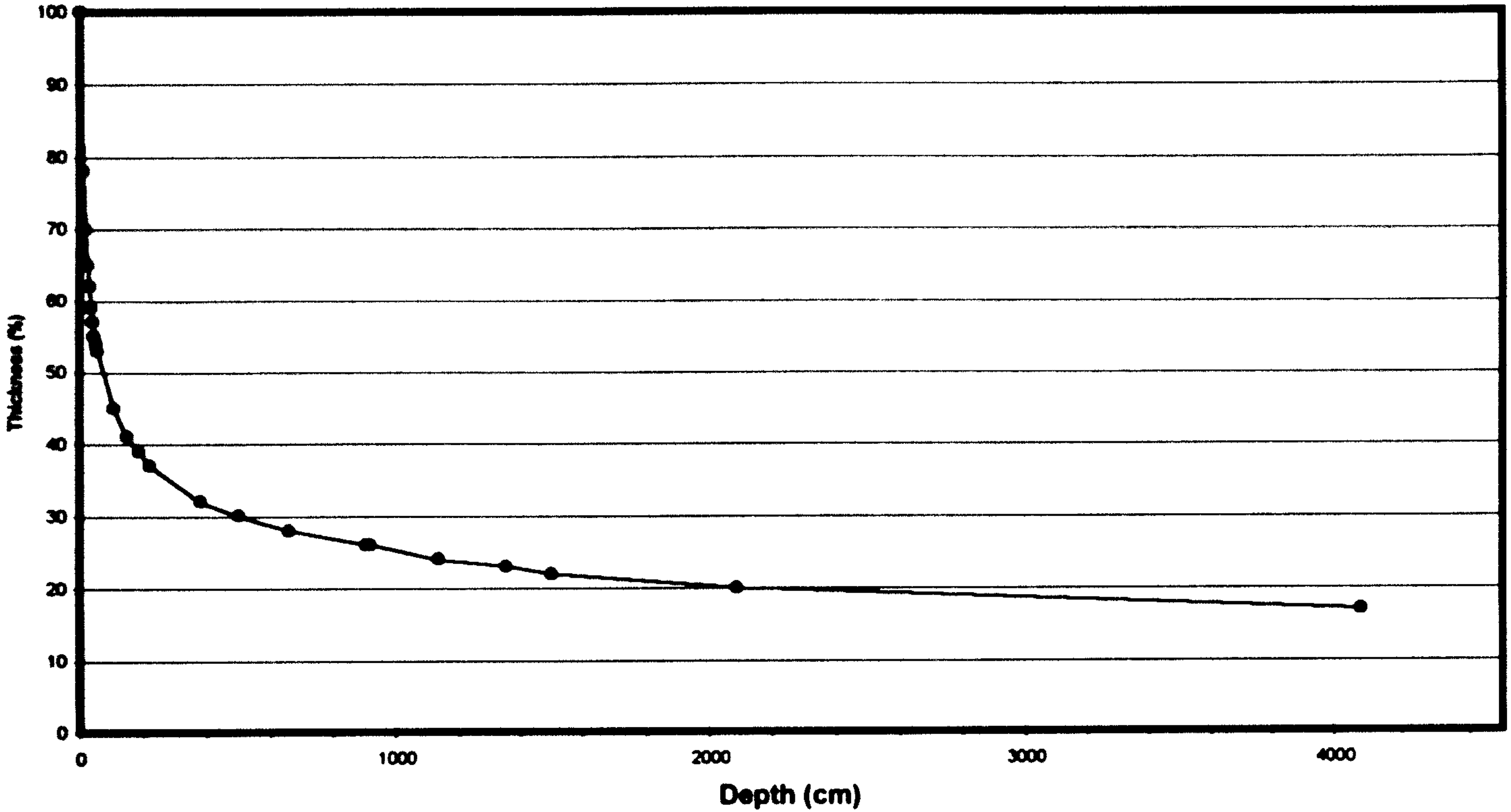
Age years	*Age difference*	*Depth (cm)*	*% of original thickness*	*Corrected thickness*	*Thickness difference*	*Rate (cm/yr)*
1430		484	29.95	1616		
	1640				2319	1.41
3070		1005	25.54	3935		
	2630				2700	1.03
5700		1489	22.44	6635		
	2950				3194	1.08
8650		2011	20.46	9829		
	11550				9324	0.81
20200		3277	17.11	19153		
mean						1.08

Fig. 7.4 Age of South African and other African peats versus depth.



Senegal (Korpijaakko, 1985)
Burundi (Pajunen, 1985)

Fig. 7.5 The relation between peat thickness and depth of burial



When data for South African peats are treated in similar fashion, the relationship between age and depth of peat for the NMC seems to be:

$$d = ma^n$$

$$\log d = \log m + n \log a$$

$$= 0.62 + 0.522 \log a \quad (4)$$

The calculated and determined ages are compared in Table 7.4.

TABLE 7.4 Calculated ages compared with measured ages for NMC peats

d = depth (cm)	age calculated	age determined	% difference
85	322	130	-59.6
93	383	450	+17.5
143	873	1 100	+26.0
235	2 262	4 840	+113.9
140	839	770	-8.2
550	11 536	4 120	-64.3

Data from these peats would be unreliable for compaction determinations due to the large and highly variable discrepancies between determined and calculated ages. This could be due to the following factors:

1. climatic fluctuations
2. different peat types, eg. sedge/reed, hardwood, etc. Hardwood peat would show much less compaction than bulky, low-density plants
3. the fact that peat from three different localities are grouped together
4. too few data points.

For inland valley mire peats (Table 5.20) the relevant relationship seems to be:

$$\log d = -1.16 + 0.96 \log a \quad (5)$$

TABLE 7.5 Calculated ages compared with measured ages for valley mire peats

d = depth (cm)	age calculated	age determined	% difference
58	1 110	1 050	-5.4
87	1 693	2 580	+52.4
550	11 559	11 310	-2.2

The discrepancy between the measured and calculated age in the middle sample (Table 7.5) is probably due to the thick (± 30cm), compacted ash layer that occur immediately above this position in the peat.

TABLE 7.6 Percentage change in thickness with depth as a function of peat compaction in South African valley mire peats, based on equation (5).

year	d_1 (cm)	years	d_{10} (cm)	change	%
1	0.07	10	0.63	0.56	100
11	0.69	20	1.23	0.54	96
21	1.29	30	1.81	0.52	94
31	1.87	40	2.39	0.52	93
41	2.45	50	2.96	0.52	93
101	5.81	110	6.31	0.50	89

The South African valley mire peat exhibits a compaction ratio much lower than that of the Burundi peat, most likely pointing to a higher degree of humification due to a lower tempo of peat formation and resultant denser peat at equivalent levels within the deposits.

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8 UTILISATION POTENTIAL OF PEAT

".... wetlands are productive ecosystems, they are also very specialised and well adapted ones. Although they are extremely valuable resources, they have, in their natural state, very little direct economic value, other than fisheries development." - Thompson (1976).

Currently little diversity exists in peat usage in South Africa. However, peat represents an important commodity in the daily lives of many South Africans, notably in the agricultural and horticultural fields. Mires are natural sponge areas that play an important role in the storage and recharge of groundwater and also represent significant ecological niches for a great variety of fauna and flora. Peat is also an excellent natural filter for cleaning and sterilising run-off waters.

Other than the above very important applications, peat has also been exploited by man for use in various technological processes, power generation, agriculture and the chemical industries. World production figures for fuel and horticultural peat are shown in Table 8.1 (World Bank/Bord na Mona, 1984).

8.1 Energy

The energy content of peat, expressed as its calorific value, varies between different peat types. The utilisation of this energy resource in Europe, mainly as a domestic fuel is of considerable antiquity. The Soviet Union has exploited its peat deposits by running a total of seventy power stations mainly on milled peat. Currently Latvia, Russia, Byelorussia and the Ukraine has capacity in excess of 4000 MW (Lappalainen, 1996). Other countries which use peat to generate electricity are the Republic of Ireland (six peat fired power stations with a combined capacity of 440 MW), Finland (2 500 MW, Lappalainen, 1996) and Scotland.

The use of peat as a domestic fuel is declining in the western world, but still persists in remoter areas of Ireland, Scotland, Germany, Finland and Russia. It is expected that energy peat use will increase rapidly in the Baltic countries, especially Latvia where energy peat production has intensified.

However, peat as a renewable energy source in underdeveloped countries is receiving increasing attention world-wide (World Bank/Bord na Mona, 1984; Heikurainen, 1985, Smuts, 1989b). Much work is underway in the fields of exploration and appropriate technology development with a view to the sustainable use of peat as energy source (Wade, 1985).

TABLE 8.1 World Peat Production 1980 (10^3 t/a, 40% moisture content) (World Bank/Bord na Mona, 1984).

COUNTRY	FUEL	HORTICULTURE	TOTAL
USSR	80 000	120 000	200 000
Ireland	5 570	380	5 950
Finland	3 100	500	3 600
F R Germany	250	2 000	2 250
China	800	1 300	2 100
USA	0	800	800
Canada	0	490	490
Poland	0	280	280
Sweden	0	270	270
Czechoslovakia	0	270	270
GDR	0	170	170
UK	no data	170	170
France	50	100	150
Denmark	0	110	110
Norway	1	83	84
New Zealand	0	10	10
Others	100	2 900	3 000
TOTAL	c. 90 000	c. 130 000	c. 220 000

8.2 Horticultural/ agricultural potential

In all countries apart from Russia, Finland and Ireland, the major use of peat is in agriculture and horticulture (Tables 8.1 and 8.2). Here its value is dependent upon a variety of properties, (1) Its organic content and high energy capacity makes peat a valuable metabolic substrate for soil microflora, hence serving the purpose of an organic manure,

(2) The fibrous nature of peat and its resulting water holding capacity assists water retention in soils and improves soil structure, (3) The high base exchange capacity of peat makes the commodity valuable for the retention of cations in the soil, particularly if the soil is low in clay content, (4) Peat alters the physical properties of soil, especially its thermal properties, because of its very high specific heat. This will affect both the microbes and higher living organisms in the soil.

TABLE 8.2 WORLD HORTICULTURAL PRODUCTION, RESERVES AND RESERVE BASE: 1992 (10^3tons) (Cantrell, 1993).

	Mine Production		Reserves	Reserve Base
	1991	1992		
USSR[1]	166 000	166 000	5 320 000	160 000 000
Ireland	7 710	8 500	171 000	900 000
Finland	3 000	6 000	70 000	7 000 000
Germany	1 665	1 600	46 000	500 000
Canada	840	900	24 000	336 000 000
USA	697	730	16 000	7 000 000
Others	2 921	3 000	3 000	1 600 000
World total[2]	182 833	186 730	5 700 000	510 000 000

The organic content of peat is important both as an energy reserve for microflora and as the site of its high base exchange capacity. Peat must therefore be defined according to its organic content for horticultural purposes. The level accepted by the Federal Trade Commission of the United States is 75 % organic matter, below

[1] As constituted before December 1991.

[2] May be rounded.

which it is illegal to market a commodity labelled as "Peat" (Edgerton, 1969). These figures are different in Eurasia where peat is defined as material with more than 50 % organic matter.

Peats formed under more ombrotrophic conditions will contain less inorganic (ash) material than those formed under rheotrophic conditions. For example South African swamp forest peat or reed/sedge peat from a domed deposit may contain less than 10 % of its dry weight as ash. Raphia peats formed under rheotrophic conditions generally contain over 20 % ash.

The sponge-like properties of peat make it important as a means of retaining water in sandy soils. Again, the water holding capacity of a peat depends to a large extent on the type of plants from which it was formed. Below is a list of the minimum water holding capacity for various peat types (Table 8.3).

TABLE 8.3 Water Content and minimum waterholding capacity of Saturated Peats (Lucas et al., 1971).

Volume Weight g/l	Water Content g/l	Total Weight g/l	Water Content % wet	WHC* % dry	Peat Type
44	960	1 004	95	2 010	white Sphagnum
88	930	1 018	91	970	Sphagnum
160	890	1 050	85	554	fibrous reed/sedge
240	835	1 075	78	346	decomposed reed/sedge (hemic)
320	780	1 100	71	242	peat humus (sapric)

* - Water Holding Capacity

These figures apply to peat samples which have been saturated with water for 18 - 24 hours and then dried at 105°C to constant weight. The water holding capacity of peat is a feature associated with the capillarity of its fibrous structure. It is useful therefore to obtain some measure of its fibrousness. For this purpose a 'fibre' is defined as having a minimum length of 0.15 mm and a grading system has been devised by the American Society for Testing and Materials (ASTM) based on the percentage fibre content of a peat, where:

$$\% \text{ fibre content} = \frac{\text{dry weight of fibres longer than 0.15mm} * 100}{\text{total dry weight}}$$

Edgerton (1969) reports that Sphagnum peats tend to have fibre contents of over 66%, reed/sedge peats 33 - 66% and humus peats less than 33%. However, this measure is probably more closely related to the degree of humification than the nature of the peatforming vegetation.

Horticulture and agriculture probably represent the most important world use of peat. In the United Kingdom 90% of the annual peat harvest finds its way onto the horticultural market, a total of 170 000 tons, in addition to which a further 60 000 tons are imported, mainly from the Irish Republic each year. In 1991 the United States harvested 800 000 tons of peat for horticultural use. This represents a total of $18 million ($23 per ton f.o.b.) worth of peat, which makes peat exploitation clearly a profitable venture (Harper, 1992).

A fairly recent development in the horticultural industry is the use of fibre pots made of compressed peat and wood/paper pulp. These serve the various functions listed above together with facilitating transplantation of young plants by avoiding root disturbance. Roots can penetrate the pots and the latter eventually decompose in the soil. Norway has led the world for many years in the production of these peat pots. Other countries involved in the pot making industry include Denmark, Ireland, Czechoslovakia, Poland, Russia and Japan (Tomczuk, 1988). The latest automatic Russian peat pot machine produces 33 million pots per unit per year (Anon., 1988).

8.3 Chemical feedstock and insulation potential

Poorly humified Sphagnum peat is rich in carbohydrates which are easily hydrolysed - yields of monosaccharides of 45 - 55% dry weight have been obtained on hydrolysis. Despite this, raw peat is not easily digested and assimilated by animals and is of little value as a stock feed, mainly because the easily hydrolysed carbohydrates are enclosed within tough sheaths. However, liberation of these low molecular weight polymers provides a useful growth medium for yeasts which can then be used for fodder. The All-Union Peat Research Institute in Leningrad (now St Petersburg) has developed a method where peat is treated with unslaked lime and non-protein nitrogenous compounds at 115°C and 70 kPa for 2 hours to produce an improved peat-based food used for cattle and pigs (Anon., 1988).

Other chemical constituents of peats which are used in industry are waxes, humic acids, bitumens, resins, activated carbon, molasses and oils (Spedding, 1988). These are used in Russia and other ex-Soviet Republics in many industries, including machine building, plastics, paper products, leather, paints, polymers, varnish and dyes.

8.4 Cultivation of peatlands

The most acute problem involved in the cultivation of peatlands is the control of water, since the majority of domesticated plants require a soil water regime which does not involve waterlogging. Thus drainage is usually necessary, but the extent of the drainage will vary with the crop to be raised.

On a world scale, the most important type of agriculture associated with peatlands is forestry. Since the majority of commercial tree species do not grow well in waterlogged environments, drainage of some type is usually necessary, even if it involves only a ploughing of the surface peat into ridges and furrows.

The means of affecting the correct degree of drainage will depend on the physical properties of the particular peat type, since the degree to which lateral seepage of water occurs in peat varies considerably. For example, in Ireland on domed mire peats it has been found that ditches of 1 m in depth have little effect upon the water at distances greater than 1.8 m from the ditch edge. On the other hand, on a sedge bog in Newfoundland, appreciable lowering of water levels was observed 11 m from such ditches and in South Africa reed/sedge peatlands in the Transvaal exhibit a lowering of the water up to 30 m from the ditch edge. The final water level is likely to be affected further by the specific crop grown because evaporation rates from forest are greater than those from grassland by a factor of about two, the differential being greatest in months of water deficit (Rutter and Fourt, 1965).

In addition to the problem of water levels, the levels of plant nutrients in reclaimed peat may also be limiting. Thus the majority of peats need to be fertilised with certain elements, particularly phosphorus, potassium and nitrogen before good crop yields are obtained.

The need to supply nitrate to crops in reclaimed peat is due to the impaired natural nitrogen cycle on these soils. In virgin acid peatlands there is virtually no nitrification, i.e. conversion of ammonia to nitrate, due to the absence of the necessary bacteria. When such peats are reclaimed it may take several years of liming and cultivation before these organisms are able to invade and recycle the nitrogen present in the peat. Meanwhile nitrates must be supplied to the crops grown.

In addition to forestry and pasture, reclaimed peatlands have become highly valued for growing vegetables and for horticulture. In Russia potatoes and onions are frequent crops. In the Netherlands and parts of England bulb growing is an important industry on reclaimed peat. In Africa reclaimed peatlands are primarily used by subsistence and artisanal farmers for production of bananas, tomatoes, cabbages, sweet potatoes, etc. and to a lesser degree for market gardening.

In the USA and Russia, *Sphagnum* bogs are used for growing lawn grass; seed germination on peat takes about 8 - 16 months to form a dense sward, when it can he cut into strips and rolled up for transportation.

8.5 *New technologies*

Ireland and Finland and the former USSR are undoubtedly the leaders in the development of new peat technologies. In the last few years Bord na Móna has developed very efficient peat based biofiltration systems for odorous gasses and waste water treatment. In the USA a new generation of industrial peat bioremediation products has been successfully test marketed. Work in the USA on the removal of heavy metals from waste waters has been carried out with success (Jeffers *et al.*, 1991). As an example, an oil absorbent based on Minnesota sphagnum peat was recently selected by a major US transportation company as an economic and environmentally friendly substitute for traditional clay products (Cantrell, 1993). Much work has also been done on the biogasification of peat to produce methane (Buivid *et al.*, 1980) and biochemical alcohol fuel production from peat (Wise, 1989).

8.6 *Other potential*

In the United States there has been some considerable attempt to harvest the secondary production of natural wetlands, mainly through waterfowl management. Hunting of waterfowl has long been a popular sport in the United States, but scientific control measures have become necessary to maintain a sensible cropping rate (Owen, 1971). This monetary incentive resulted in efforts being made to create and maintain wetland habitats suitable for waterfowl, both by creating artificial ponds and by retarding hydroseral successions. Wetlands are also increasingly becoming sites where people go for recreation purposes. They are important sites for game- and bird watching and fishing in South Africa and are also amongst the most sought after areas for hiking and environmental education, for example the greater St. Lucia Wetlands Park. A number of wetland sites in the eastern Transvaal have also been turned into permanent dams for the benefit of syndicated trout fishing over the last few years.

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9 CLASSIFICATION, SUMMARY AND CONCLUSION

9.1 Classification

The peatlands of Eastern and Central Africa are subdivided into three broad categories (Thompson, 1973):

1. Grass and reed swamp
2. Swamp forest
3. Tussock-sedge mires.

Furthermore, Thompson and Hamilton (1983) recognise the following mire types; blanket peats, raised (domed) peatlands and valley peatlands.

In terms of their hydrology and nutrient cycling South African mires are grouped into *bogs* and *fens / swamps* in this work (Tables 9.1; 9.2). Fens are in turn divided according to topography into *bound* and *unbound* mires each with its own subdivisions (Table 9.2). On the next lower tier mires are divided according to major vegetation types, followed by further subdivisions within each vegetation type where applicable (Table 9.3). Below the fourth tier one can further subdivide each plant type into a number of combinations, eg. mixed sedge/papyrus mire, hard wood/sedge mire, hardwood/mangrove mire or mangrove/*Phragmites* mire.

In the case of both forest and sedge/reed peatlands the main types often occur as separate components of one large mire complex. Papyrus peatlands in southern Africa are restricted to the tropical eastern coastal zone of the NMC and the Okavango Swamp Complex in Botswana. In cooler climates and higher altitudes the position usually occupied by papyrus is typically replaced by the sedge, *Schoenoplectus*. Grass mires (*Miscanthidium* spp.) are typified by very low energy conditions. They are also usually dry enough to support various *Sphagnum* species and other bryophytes. Grass mires also tend to be more acidic than most other sedge/reed mires.

TABLE 9.1 FLOW DIAGRAM FOR BOG CLASSIFICATION

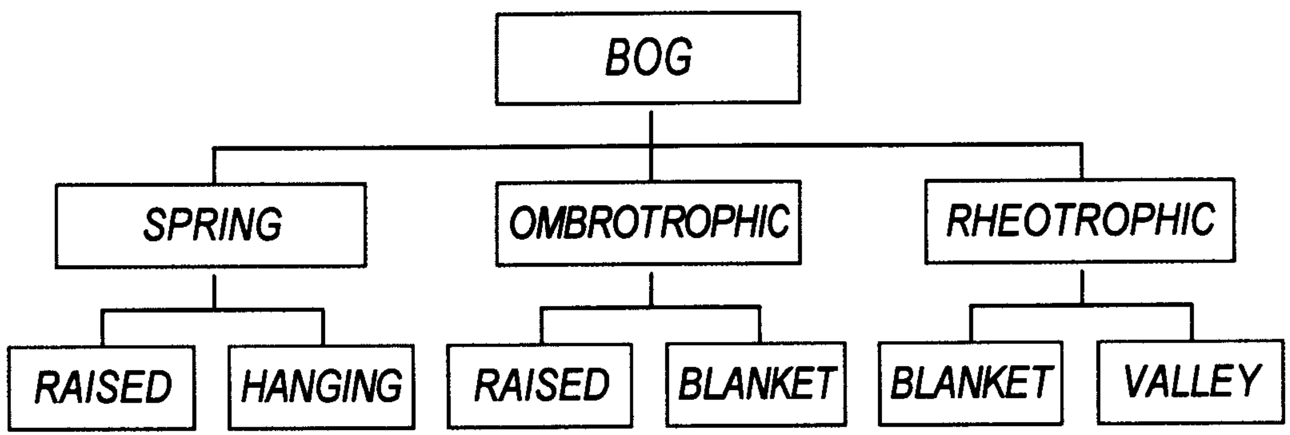


TABLE 9.2 FLOW DIAGRAM FOR FEN CLASSIFICATION

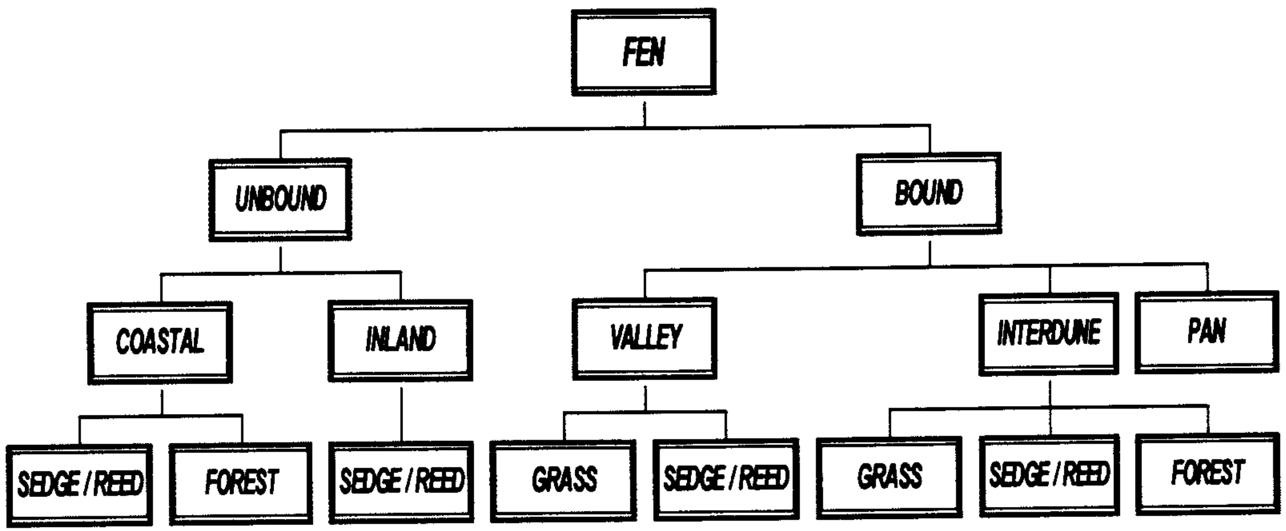
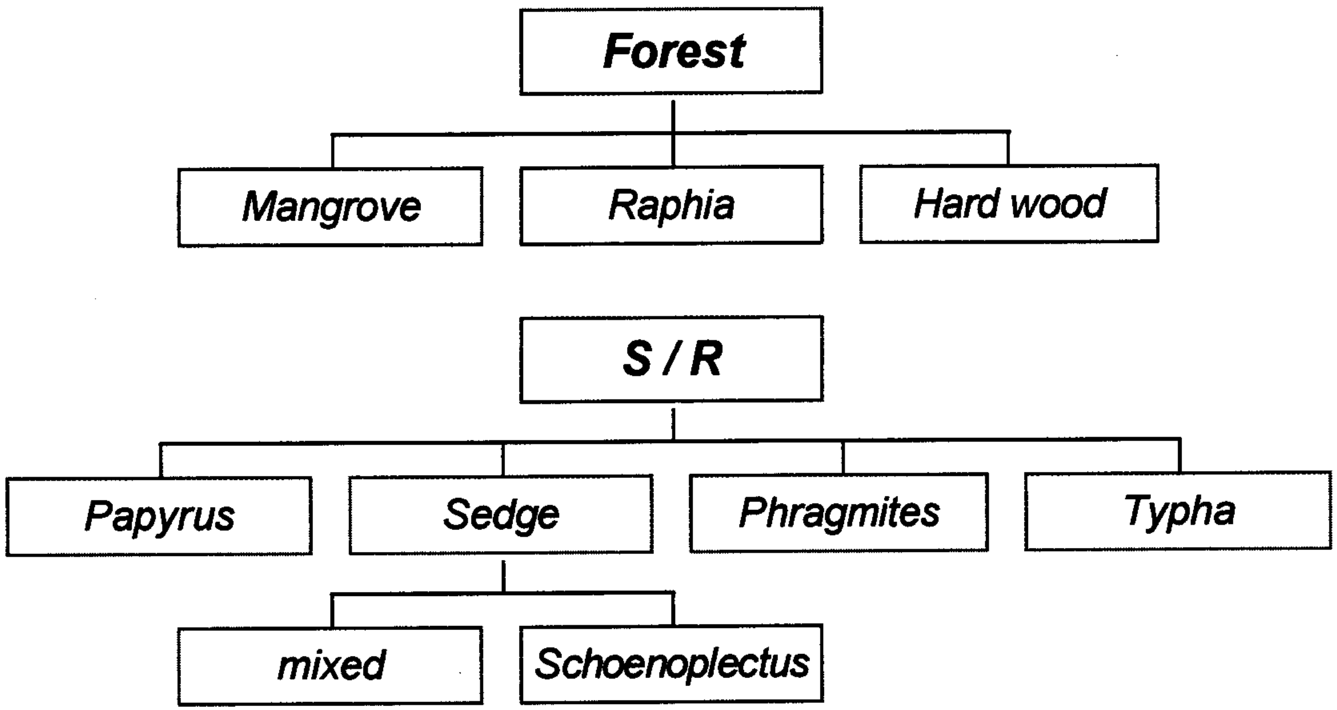


TABLE 9.3 FURTHER SUBDIVISIONS FOR FOREST AND SEDGE / REED MIRES



9.2 Conclusions

The following conclusions have been singled out for special mention:

(1) Contrary to the calorific value that Stach et al. (1982) quotes for the boundary between soft and hard brown coal it has been shown here that African peats have calorific values that often exceed this boundary. Thus, the rank parameters given by Stach et al. (1982) are dubious.

(2) Sedge/reed peats are the only peat type eligible for utilisation. However, since these peats tend to be perhydrous (rich in combustible hydrocarbons) they are too reactive for utilisation as activated carbon feedstock.

(3) Smaller, thin peat deposits generally exhibit an increase of ash content with depth; whereas larger, thick deposits tend to have ash content decreasing with depth -- this trend is more apparent towards the centre of deposits. The latter deposits are also less influenced by external ash sources.

(4) Marine influences result in a sharp drop in pollen counts.

(5) Palynology proved a useful tool in corroborating petrographic evidence in determining hydroseral succession in a mire.

(6) Stem and leaf remains are less commonly preserved than roots and are much more degraded as a result of oxidation and microbial attack in the litter layer before being incorporated into the peat.

(7) Sedge/reed peats in South Africa are more inertinitic than any other African peat, while forest peats are very similar to Togolese peats -- indicating very similar climatic, hydrological and geological conditions and vegetational composition at the time of deposition in both areas.

(8) South African peats tend to be matrix rich, with a wide range from 2% to +60% matrix.

(9) The South African sedge/reed inertinite comprises largely of fusinite -- resulting from the cyclical dry periods common to the sub-continent. Sedge/reed peats generally become more inertinitic away from the coast (i.e. from east to west) as climatic conditions become more conducive to cyclic dry periods and the resulting increase in fires and oxidation.

(10) South African peats fall in the decomposition range of 20% to 60% -- compared to other African and Costa Rican examples that cover the spectrum between 40 and 60%.

(11) The primary reaction in peatification appears to be dehydration, accompanied by decarboxylation. Demethanation is of subordinate importance in the peat stage of the coalification process.

(12) All South African peats qualify as horticultural peats in terms of their water holding capacity limits.

(13) Both fibre content and fibre length are dependent on peat type and state of humification of the peat.

(14) Determination of the relationship between peat thickness and depth of burial indicates that peat compacts very rapidly -- at a depth of less than 6 m a deposit will have compacted to 30 % of its original thickness.

(15) South African valley mire peat exhibit a much lower compaction ratio -- pointing to a higher degree of humification due to a lower tempo of formation and resultant denser peat at equivalent levels within deposits.

9.3 Resource estimation

The estimations outlined in this chapter are a first attempt at quantifying the peat resources of South Africa. It should be accepted that these figures are not complete but merely represent a bench mark from which to approach future resource calculations. A generalised reserve characterisation is presented in Table 9.4.

TABLE 9.4 GENERALISED RESERVE CHARACTERISTICS (as presented by the Department of Minerals & Energy to the African Energy Programme, 1993)

Designation	NATAL	TRANSVAAL	CAPE	TOTAL SA
Reserves (10^6 t)				
- Proven reserves	247,107	2,743	0,612	250,4
- Probable reserves				5 691,6
- Potential reserves				3 264,0
Quality Parameters (air - dry basis)				
- Moisture content (%)	12.3	9.5	11.0	10.9
- Ash (%)	20.9	28.5	21.2	23.5
- Volatile matter (%)	48.3	41.7	41.1	43.7
- Sulphur (%)	0.015-0.8	0.004-0.9	0.02-0.8	
- Fixed carbon (%)	18.5	20.4	26.7	21.9
- Calorific value (MJ/kg)	16.5	13.3	14.3	14.7
Deposit parameters				
- Thickness (m)	0.5 - 7	0.5 - 9	0.5 - 7	
- Depth (m)	surface	surface	surface	

These figures are based on a minimum peat thickness of 0.5 m and an ash content of less than 50%.

The information for Table 9.4 was extracted from the following list of indices:

Total mire area (at least 30cm peat)	± 950 000 ha
Greatest known peat thickness	7 m
Average peat thickness	1.8 m
Industrially usable peatland	± 310 000 ha
Peat suitable for harvesting	± 5 580 x 10^6 m^3
Quantity of *in situ* peat	8 780 x 10^6 m^3
Amount of peat expressed tds [3]	1 343 x 10^6 tons

9.4 Mire use in South Africa:

of the original mires the following have been used:

in agriculture	± 185 000 ha
in forestry	± 6 000 ha
currently in use (1992)	± 1 000 ha
peatland used (cut-away area) to end 1992	± 1 500 ha
used in community building (dump sites, lakes, harbours)	± 10 000 ha
protected by law [4]	± 250 000 ha

[3] TDS (total dry solids) is based on a specific gravity of 1.5 for this calculation.

[4] This represents approximately 26% of the mires in South Africa and refers to peatlands incorporated into reserves and sanctuaries under national and provincial nature conservation acts. All wetlands are protected as natural resources under the terms of Act 43 of 1983: Conservation of Agricultural Resources Act, 1983 (Anon., 1983).

9.5 *Environmental considerations*

> *"Management of this resource for better economic reward cannot, and should not be avoided, but it is most important that development should proceed wisely, so as to retain as many as possible of the characteristics which make natural tropical swamps so efficient at utilising the resources at their disposal."* - Thompson (1976).

In conclusions about the future/ well-being/ conservation/ utilisation of mires in South Africa (and the rest of the continent) it is in my view necessary to look at the situation from a decidedly African perspective. This perspective should include aspects such as the size and nature of the natural resource base, climate, demographics, socio-economics and traditional practices.

In Eurasia it may be acceptable to convert certain mire types permanently to arable land for forestry or farming but in southern Africa such practices should never be allowed - the size of the resource is simply too small and water is too precious a commodity. Similarly, to convert entire mires into dams for fishing or other recreation should also not be promoted as this removes the filtration and flood/drought buffering ability of that peatland from the ecosystem. On the other hand, to have eco-sensitive dams within large mire systems can be beneficial to fish, fowl and man. Such dams have the benefit of the mire's filtration capacity and can provide a natural open water habitat often lacking in southern African mires.

Mires are remarkably resilient ecosystems that can endure severe abuse over extended periods as proved by the mires in and around the Witwatersrand (eg. Klip Rivier, Blesbok Spruit and many others) that have survived decades of pollution, silting and burning. However, once the point of no return has been reached in the degradation of a mire, it is extremely difficult and costly to rehabilitate. As mentioned before in this dissertation, mires exist in some or other stage of hydroseral succession and thus are continually in a state of transformation. If all external factors are excluded from a mire and it is allowed to transform naturally and unhindered, that wetland will in the fullness of time make the transition to a terrestrial system and cease to exist as a mire. For this reason nature conservators must ask the question; *do they want to protect mires in order to allow them to reach a natural conclusion or do they want to protect mires to be able to show and study them at specific "moments" in their history while at the same time reaping the benefits of the natural resource?*

The choice will result in two very different approaches to mire management. If the first is selected it will be a very easy task - simply ensure a total hands-off situation and protect the mires from all possibly detrimental effects such as fire, flooding, drought or human interventions. The second option, although much more difficult to manage, is the more sensible option especially in view of the fact that it is becoming increasingly difficult in southern Africa (and Africa in general) to defend *conservation simply for the sake of conservation* policies and because mires can, with no ill effect to themselves, offer a bounty of natural resources to man, ranging from energy and building materials to food, medicines and clean water for as long as the harvesting is carried out responsibly and in accordance with strict *sustainable* exploitation principles.

In order for sensible and responsible decisions to be made about wetlands by anybody concerned with them (for whatever reason), it is of paramount importance that as much information as possible be collected about wetlands over a broad spectrum of scientific expertise and made available to the decision makers. There are no hard and fast rules that can be applied like a blanket when it comes to peat and mire management questions. Each situation must be evaluated on its own merits based on the accumulated knowledge bank.

I believe, for example, that scientists, conservators and managers responsible for the well-being of certain South African mires that refuse to admit or simply not believe that significant peatlands occur in those areas, are irresponsible and short sighted. This ignorance can and indeed has led to the unnecessary loss or ruin of some important mire systems in South Africa now and in the past.

"The world .....rarely recognised any new reality in its beginnings. Reality seemed to have to grow great and terrible, like an angry giant hammering on the doors of closed minds, before people would take notice and then, alas, it was almost invariably too late."

- Laurens van der Post, *A Story Like The Wind.*

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