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HOLOCENE HISTORY OF TOBACCO RANGE,

BELIZE, CENTRAL AMERICA

BY

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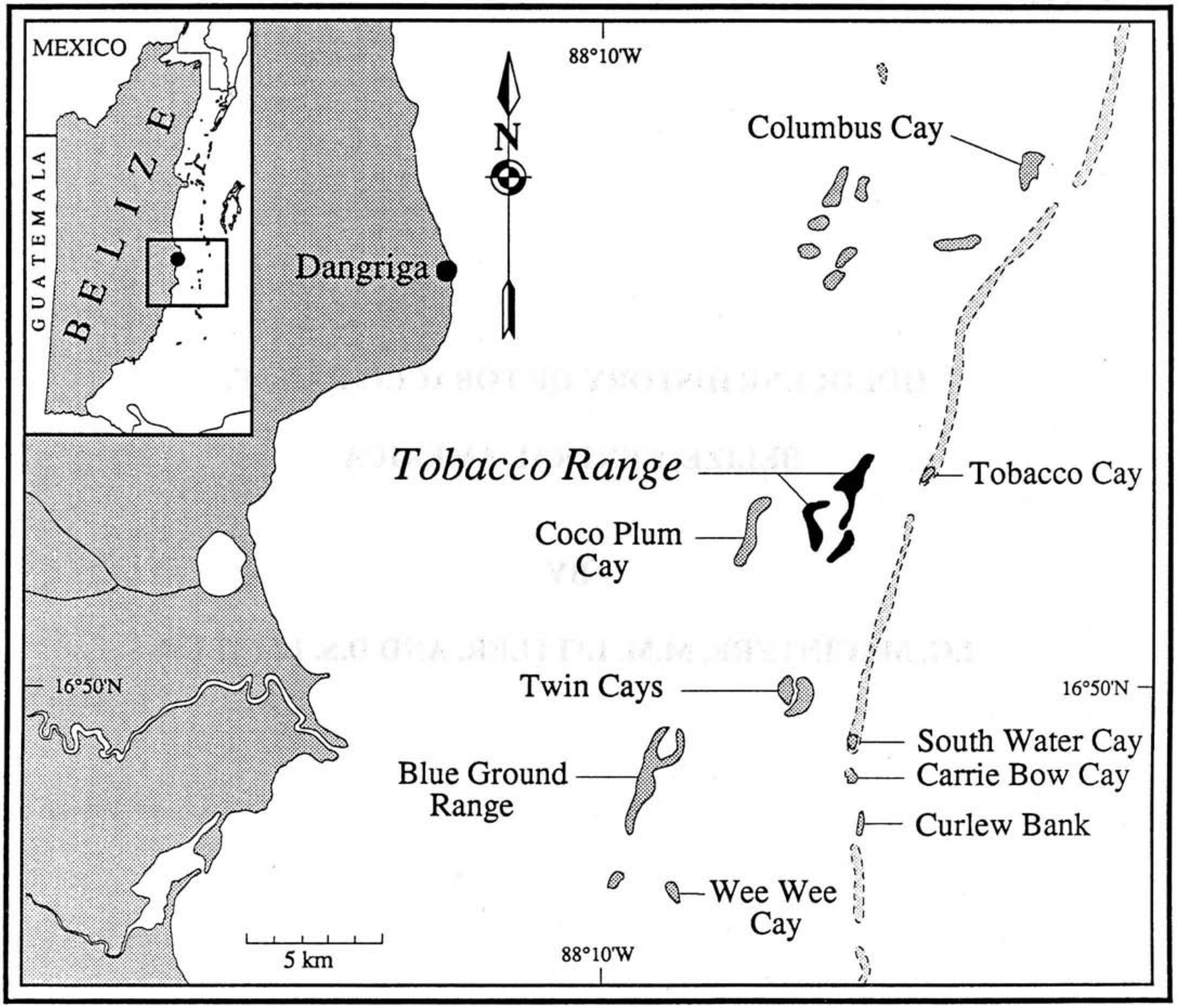

Figure 1. Index map showing the location of the Tobacco Range mangrove island complex on the outer platform of the Belizean Barrier Reef.

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ABSTRACT

Sediment-core samples from seven vibracores and ten soil-sampling probes across the northeastern island of Tobacco Range indicate that this mangrove complex has been a mangrove community throughout its entire Holocene history. Samples from cores and probes documented some of the thickest mangrove peat sections ever recorded, up to 10 m thick, with thin basal mud sections overlying the eroded Pleistocene limestone surface. This peat consists of upper sections of spongy, well-preserved "broad-fibered" peat with readily recognizable plant remains, which overlies a partially decomposed dense "fine-fibered" peat with almost no macroscopic plant fragments. The basal muds, which consist of a mixture of calcareous and non-carbonate sediments, are probably a reworked soil. Peat-forming mangrove communities became established on Pleistocene limestone areas of topographically high relief about 7,000 yrs B.P. and accumulated peat at rates of up to 4.3 m/1000 yrs, which allowed them to keep pace with the rising seas of the Holocene transgression. Vibracores off the west coast reveal thick sections of soft fine-fibered peat underlying more coherent broad-fibered peat. Undercutting has produced extensive fracturing and slumping of the peat deposits that has resulted in spectacular sea-floor relief. Radiocarbon dates of Tobacco Range peat samples confirm that the late Holocene history of sea-level rise reported for other western Atlantic areas is valid for Belize.

INTRODUCTION

Mangrove peat recovered in sediment cores from several studies (Purdy, 1974; Ebanks, 1975; Halley et al., 1977; Shinn et al., 1982) indicates that mangrove communities were established on the Belizean continental shelf soon after this shelf was flooded by the rising seas of the Holocene transgression. Most of these mangrove communities were eventually drowned and buried under calcareous marine sediments, except in areas of higher topographic relief on the underlying Pleistocene surface, where the mangrove communities survived to form some of the thickest Holocene peat sections ever recorded -- one such area is Tobacco Range (Fig.1).

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In this study we analyzed sediment cores to investigate the Holocene history of the Tobacco Range mangrove complex and to see how these thick peat accumulations relate to other reports of Holocene Belizean peat deposits. We were particularly interested in how radiocarbon dated samples from this and previous studies provide a better understanding of the late Holocene sea-level curve for the Belize area. In addition, we collected subsurface data in an attempt to explain the unique fracturing and slumping of submerged peat off the northwest coast of the Tobacco Range island complex.

METHODS

During March 1987, seven continuous sediment cores were collected using a vibracorer with aluminum pipes, each of which was 9 m long with a diameter of 7.6 cm and fitted with a core catcher. (Fig.1). Six of these cores were collected along a transect (oriented southeast to northwest) that bisects the northeastern and largest island of the Tobacco Range mangrove complex (Fig.2), five of which were collected from the west coast -- one on the island, one from the shallow-water unfractured peat surface, and three from deeper areas of slumped peat (Fig.3).

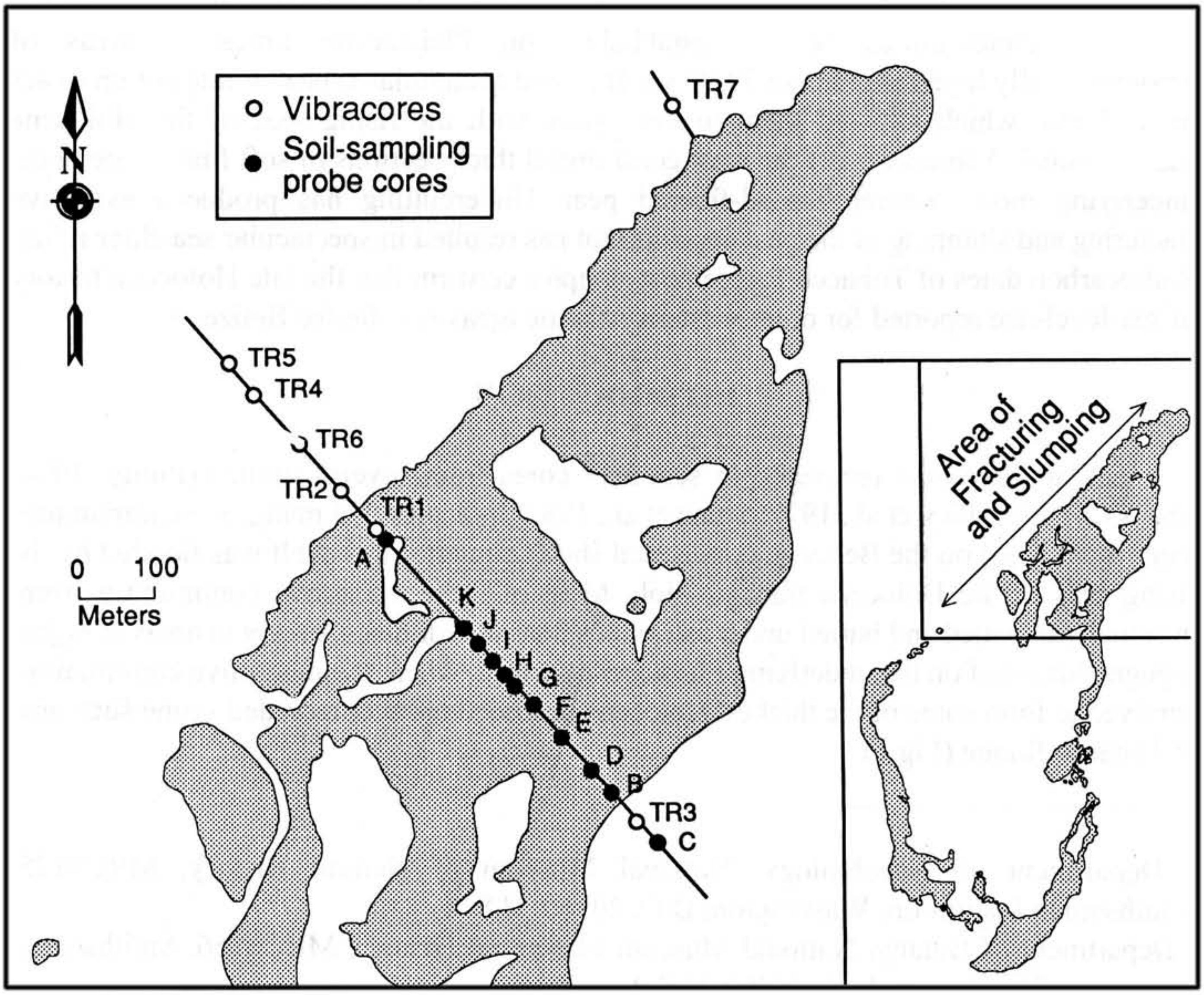

Figure 2. Map of the northeastern island of Tobacco Range with locations of vibracores and soil-sampling probe cores.

Figure 3. Vibracoring underwater in area of slumped peat off the west coast of Tobacco Range. Depth 7 m.

Figure 4. Vibracoring in shallow water off the east coast of Tobacco Range.

A single core was collected along the transect line off the shallow windward east coast (Fig.4). In addition, one core was collected close to the north point off the west coast of this island near fresh fractures in the *Thalassia*-covered submerged peat surface. The depth of penetration was recorded at each vibracore site and compared with the length of core recovered to establish a compaction correction that was applied to the peat sections in each core. Cores were left in the aluminium pipes and cut into 3 m sections that were capped and shipped for laboratory analyses.

To obtain a more complete record of peat accumulation along the study transect, we returned in March 1989 to collect short core samples at varying depths with Macaulay and Davis soil-sampling probes (Fig.5). A total of eleven sites were established on the study transect that extended our subsurface sampling across the entire island to a point 80 m off the east coast (Fig.2). These samples were described in the field and preserved in plastic bags for later analyses.

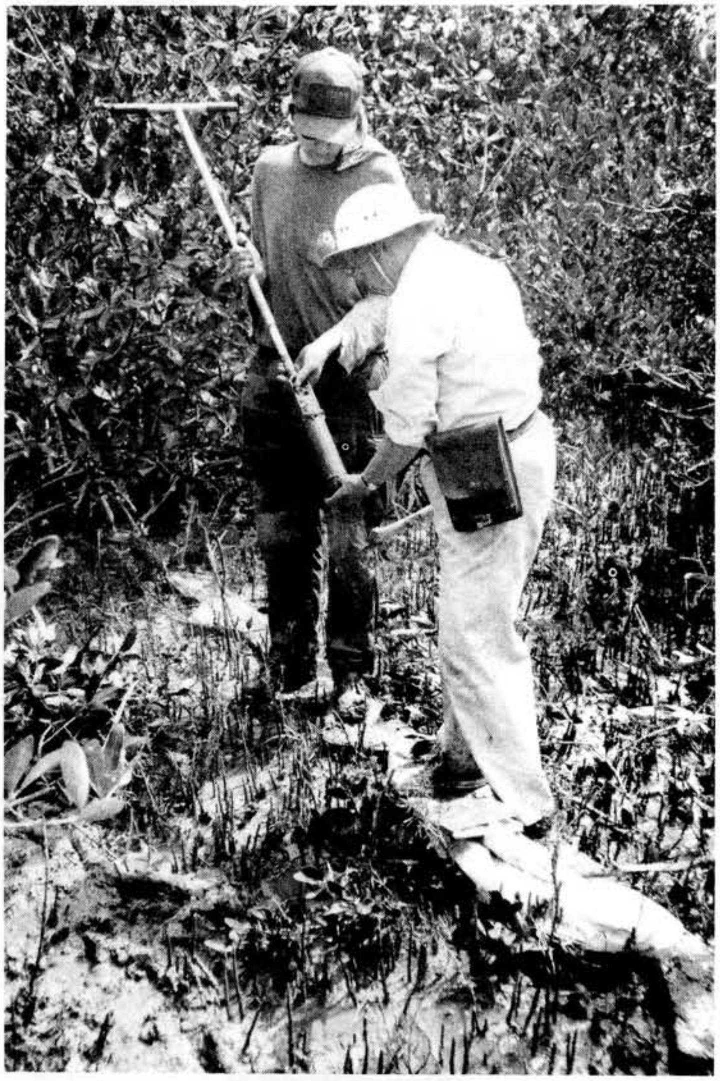

Figure 5. Collecting a peat sample from a Macaulay soil-sampling probe.

In the laboratory, carbonate and non-carbonate mineralogies were determined by standard power X-ray diffraction techniques using CuKα radiation (Chave,1954; Milliman, 1974). The mole% magnesium carbonate in calcites was calculated from d(211) spacings in relation to quantitative curves constructed by Goldsmith and Graft (1958).

Radiocarbon dates were determined by Beta Analytic Inc. using a Libby half-life of 5568 years and 95% of the activity of the National Bureau of Standards oxalic acid was used as the modern standard. Each sample was carefully examined under the microscope to remove rootlets that were noncontemporaneous with the peat being dated. All carbonate material was removed with an acid pretreatment. After thorough washings in distilled water, each sample was analyzed. No corrections were made for the DeVries effect, reservoir effect, or for natural isotopic fractionation.

RESULTS

Subsurface Facies

As can be seen from the data plotted on a cross-section along the transect (Fig.6), except for thin basal sections of terrigenous clay above the Pleistocene surface, almost the entire series of core intervals, both from the island and offshore, consisted of mangrove peat with a maximum thickness of 10 m.

This peat can be classified as two basic types: 1) The well-preserved "broad-fibered peat", which tended to be brown to reddish brown in color with a spongy texture of flattened coarse fibers, roots, and rootlets (Figs.6 and 7) "fine-fibered peat" that was usually dark brown to brownish black with a generally uniform pasty dense texture of fine fibers (Figs.6 and 8). This partially decomposed peat exhibited almost no identifiable plant remains in hand specimens and smeared readily between the fingers. All of this peat was probably derived from mangrove communities similar to those found on Tobacco Range today. A more detailed description of the composition and chemistry of these peat deposits is given by Cameron and Palmer (1995, this volume).

The only other significant facies in the sediment cores was the basal mud that was found on the erosional Pleistocene limestone surface. This basal mud was watery in some sections and highly variable in peat content, which was reflected in its color that varied from medium grey to grey brown. The carbonate content was also highly variable, ranging from 30% to 80%. Much of this carbonate is composed of lithic fragments derived from the underlying Pleistocene limestone. One large *Porites porites* coral fragment from the basal mud in TR 4 (Fig.9) was found in X-ray diffraction analysis to contain 14% calcite (< 2 mole % $MgCO_3$), clearly indicating that this coral was subaerially exposed and therefore derived from the Pleistocene substrate. Along with this residual carbonate debris, there were also some Holocene skeletal grains, which were mostly marine molluscan and echinoid fragments.

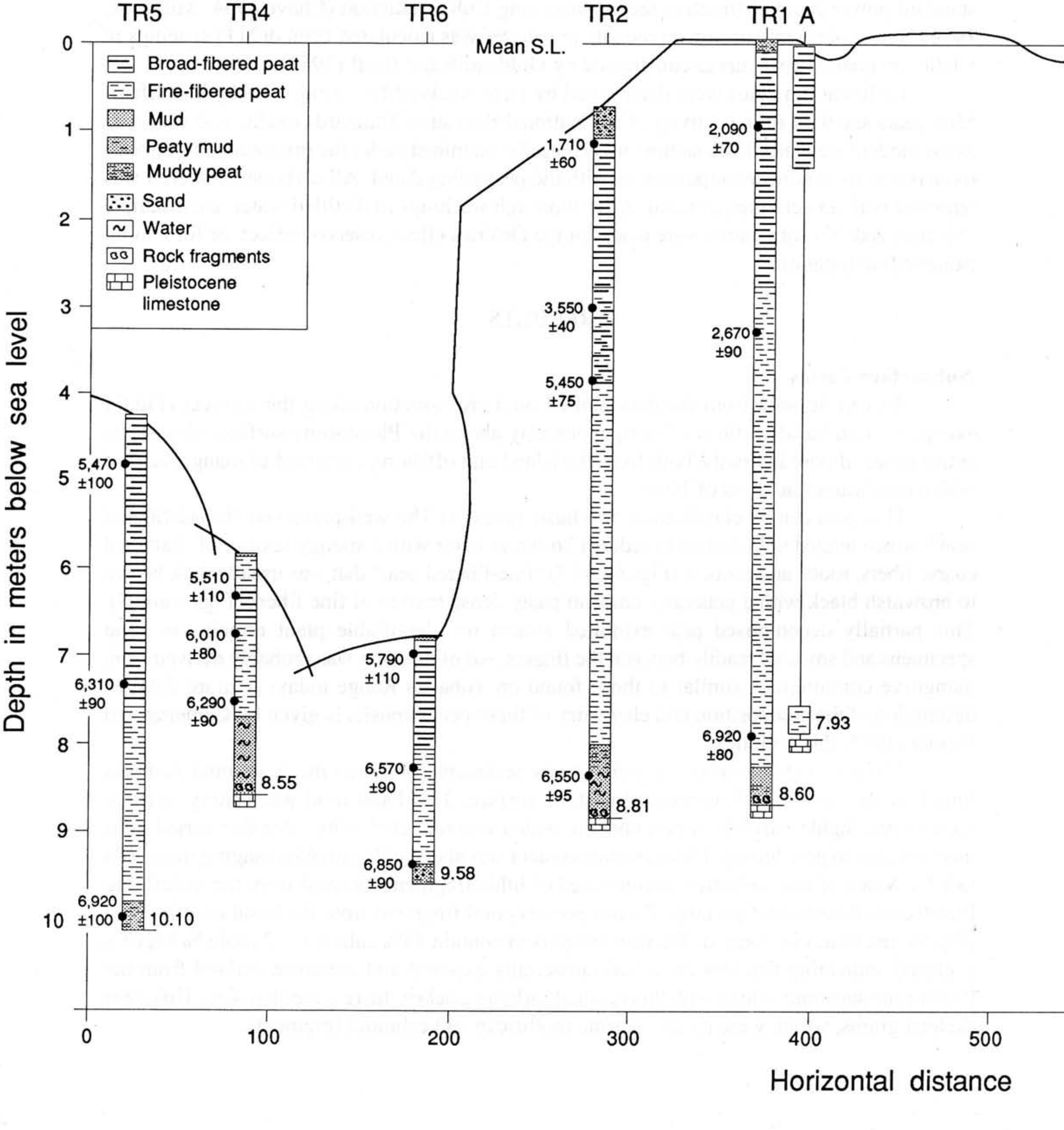

Figure 6. Cross section along the vibracore and soil-sampling core transect across northeastern island of Tobacco Range (see Fig.2). Subsurface distribution of peat and sediments is shown along with the locations of radiocarbon-dated peat. The total depth below mean sea level in meters is indicated at the base of each core log.

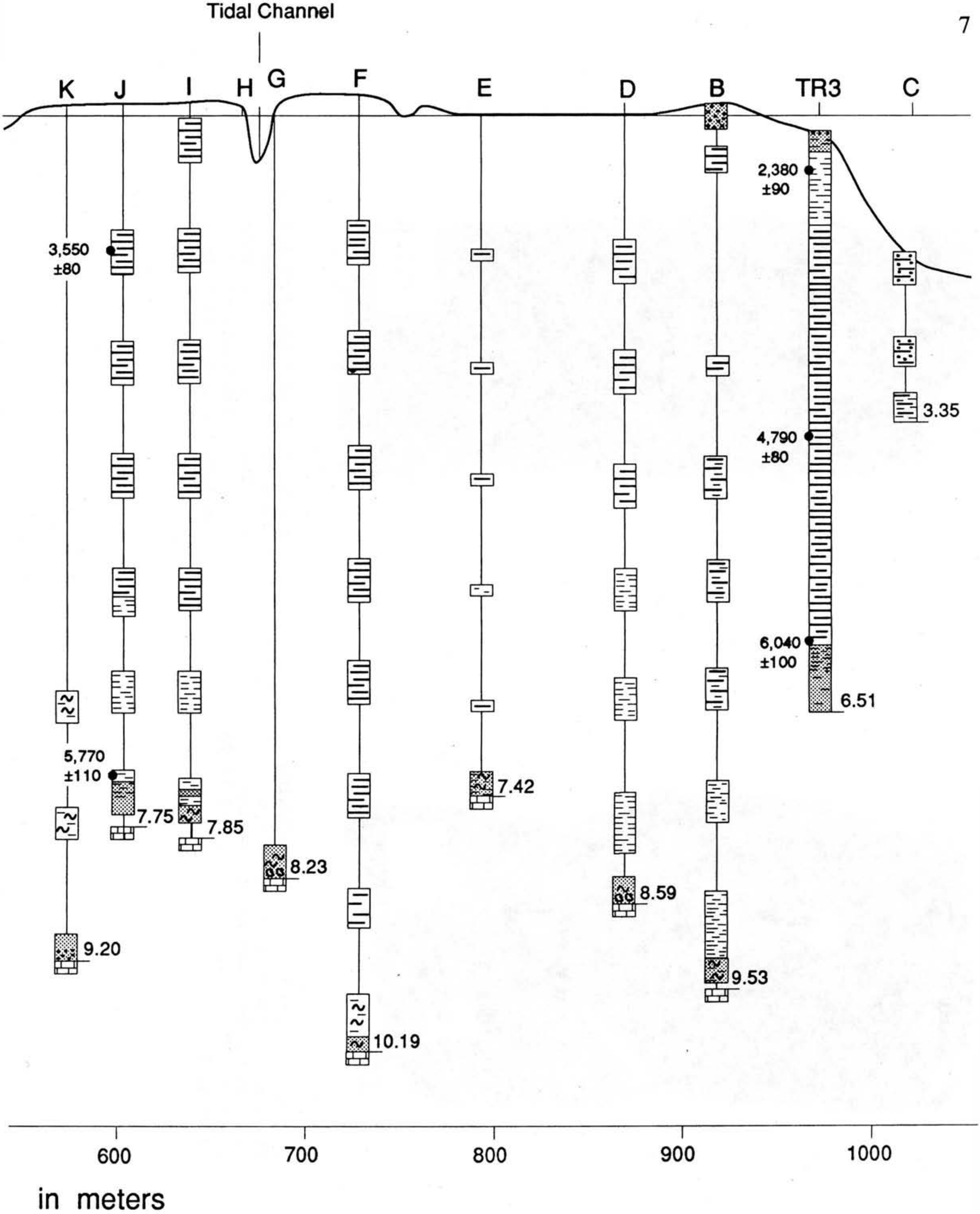
Tidal Channel
K
J
I
H
G
F
E
D
B
TR3
C
3,550
±80
2,380
±90
4,790
±80
6,040
±100
5,770
±110
3.35
6.51
7.42
7.75
7.85
8.23
8.59
9.20
9.53
10.19
600
700
800
900
1000
in meters

Figure 7. Broad-fibered peat showing the open spongy texture of coarse flattened fibers and plant remains. Vibracore TR 1. Depth interval 11 to 23 cm below MSL.

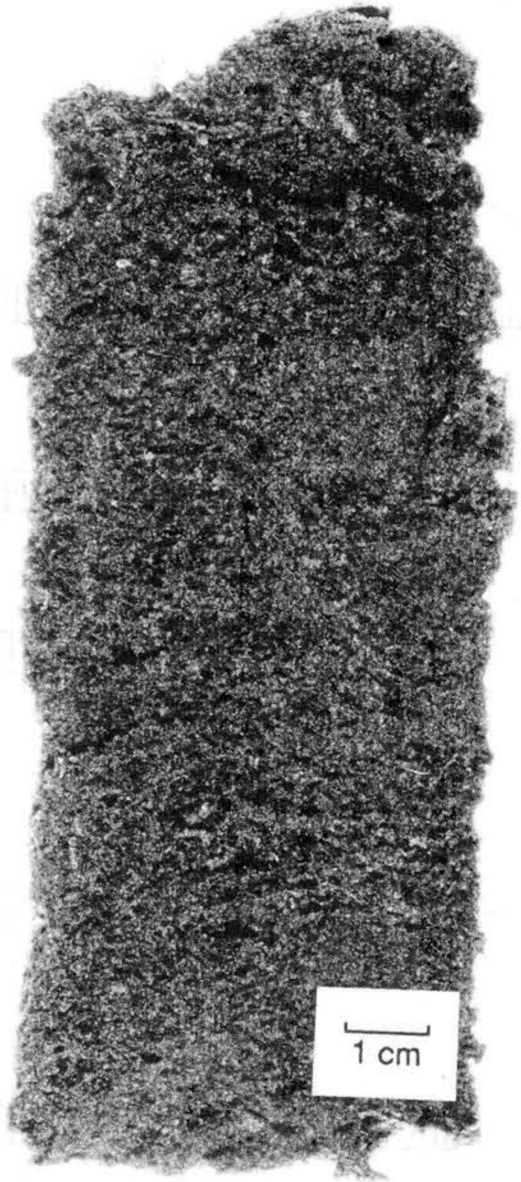

Figure 8. Fine-fibered peat with characteristic uniform and relatively dense texture with a lack of recognizable plant remains. Vibracore TR 1. Depth interval 5.98 to 6.13 m below MSL.

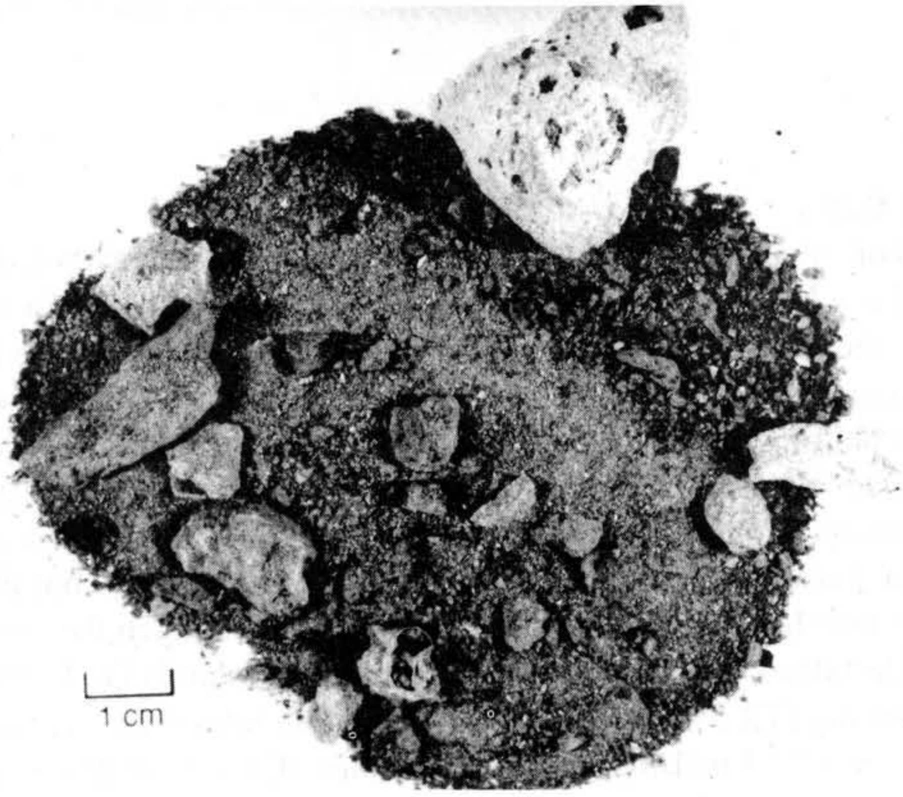

Figure 9. Basal mud sample from vibracore TR 4. Note rock fragments and gastropod. Large fragment is coral (*Porites porites*) that was eroded from underlying Pleistocene limestone. Depth interval 7.68 to 8.55 m below MSL.

One consistent feature of the basal mud was the presence of both quartz and kaolinite/chlorite with some secondary pyrite , based on X-ray diffraction analyses of insoluble residues of the mud-size fractions (<4μm) of all basal muds (Fig.10).

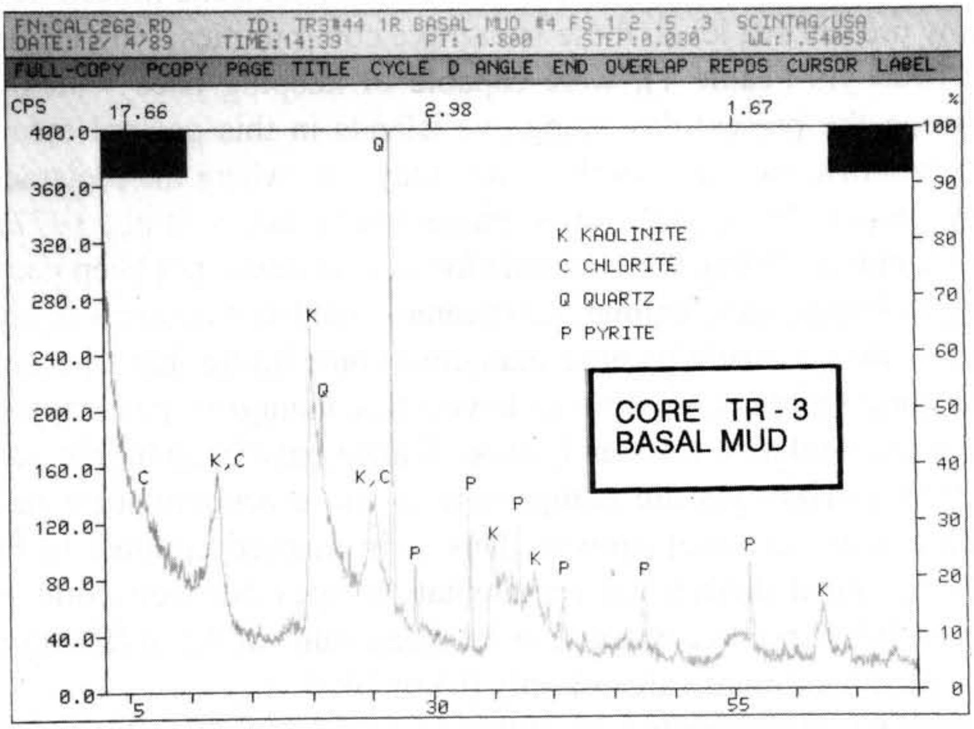

Figure 10. X-ray diffractogram of minerals in the non-carbonate fraction of the basal mud from vibracore TR 3.

Radiocarbon Dates

A total of twenty three mangrove peat samples were radiocarbon dated (Table 1). All of these dates have been plotted on the cross section (Fig.6), except for the two dates from TR 7, which is the one vibracore collected north of the transect line. As mentioned earlier, corrections were made for the thickness of peat sections that were compacted during vibracoring. In plotting the depth locations of dated peat samples, however, no corrections were made for natural compaction of the peat, which is difficult to quantify (A. C. Neumann, personal communication, 1995). Samples near the base and from near the top of peat sections would probably show little effect of natural compaction, but the few midsection samples could have been plotted at depths below those at which the peat was formed.

The oldest dates were from the west coast of the island (TR 1 - 6920±80) and from the area of slumping (TR 5 - 6920±100). Accumulation rates were highly variable, ranging from a maximum of 4.3 m/1000 yrs to a minimum of 0.4 m/1000 yrs. The accumulation rates for the top sections of two cores in areas of present-day mangrove growth were both representative of the minimum rates for mangrove peat accumulation in the Tobacco Range system (0.5 m/1000 yrs for TR 1 and 0.5 m/1000 yrs for J).

DISCUSSION

History of growth of Tobacco Range

If we accept the general trend for the late Holocene rise in sea level shown in Figure 11, we can see that mangrove communities were thriving in deeper lagoonal areas (Halley et al., 1977) before the Pleistocene relief below Carrie Bow Cay was flooded about 8000 years ago. In areas such as Tobacco Range, where the Pleistocene limestone surface is less than 10 m below present sea level, these mangrove communities, with accumulation rates of up to 4 m/1000 yrs (Table 1), were capable of keeping pace with the rising seas, eventually forming the present-day mangrove islands in this general area of the Belize Barrier Reef. In contrast, the areas south of our study site, where the Pleistocene limestone is considerably deeper, 15 m at Boo Bee Patch Reef (Halley et al., 1977) and 20 m at Channel Cay (Westphall, 1986), the accumulation of peat could not keep pace with the late Holocene rising seas and coral communities became established on areas of high Pleistocene limestone relief. In the Channel Cay area, mangrove communities have become established on some of the coral buildups, which now have a thin mangrove peat capping.

The peat accumulation rates at Tobacco Range have been highly variable, but the values of up to 4 m/1000 yrs are comparable to those accumulation rates commonly associated with active coral-reef growth. This is in marked contrast to Purdy's (1974) findings where he noted differential sedimentation rates between coral accumulations (average of 2.7 m /1000 yrs) as compared to the mean value of 0.2 m /1000 yrs for lagoonal peat deposits, with a maximum value of only 0.3 m/1000 yrs.

The overall late Holocene history of this area is one of a flooding of the continental shelf about 9000 yrs ago, initially through passes in the outer Pleistocene ridge system that provided the foundation for the present-day barrier reef. With the flooding of the inner lagoonal areas, mangrove communities began to flourish. Some of these communities in

Table 1
Radiocarbon Dates and Accumulation Rates for Mangrove Peat Samples from Tobacco Range, Belize

Core or Probe Hole	Depth(m) of Recovery Below Mean SL	C-14 Laboratory Number	C-14 Age Years BP ±SD	Accumulation Rate m/1000y
TR 1				0.5*
	0.97m	Beta - 22916	2090 ±70	
				4.0
	3.30m	Beta - 22917	2670 ±90	
				1.1
	7.91m	Beta - 22918	6920 ±80	
TR 2	1.16m	Beta - 22919	1710 ±60	
				1.0
	3.01m	Beta - 22920	3550 ±90	
				0.4
	3.84m	Beta - 22921	5450 ±75	
				4.1
	8.34m	Beta - 22922	6550 ±95	
TR 3	0.62m	Beta - 22923	2380 ±90	
				1.2
	3.51m	Beta - 22924	4790 ±80	
				1.9
	5.82m	Beta - 22925	6040 ±100	
TR 4	6.33m	Beta - 22926	5510 ±110	
				0.8
	6.75m	Beta - 22927	6010 ±80	
				2.8
	7.53m	Beta - 22928	6290 ±90	
TR 5	4.81m	Beta - 22929	5470 ±100	
				3.0
	7.34m	Beta - 22930	6310 ±90	
				4.3
	9.93m	Beta - 22931	6920 ±100	
TR 6	6.97m	Beta - 22932	5790 ±110	
				1.7
	8.25m	Beta - 22933	6570 ±90	
				4.0
	9.38m	Beta - 22934	6850 ±90	
TR 7	2.42m	Beta - 22936	3050 ±80	
				1.6
	8.04m	Beta - 22937	6570 ±80	
J				0.5*
	1.50m	Beta - 31605	3550 ±80	
				2.6
	7.19m	Beta - 31606	5770 ±110	

* Accumulation rate for top section of actively growing mangrove island--taking into account 2 cm (TR 1) and 10 cm (J) relief above mean sea level.

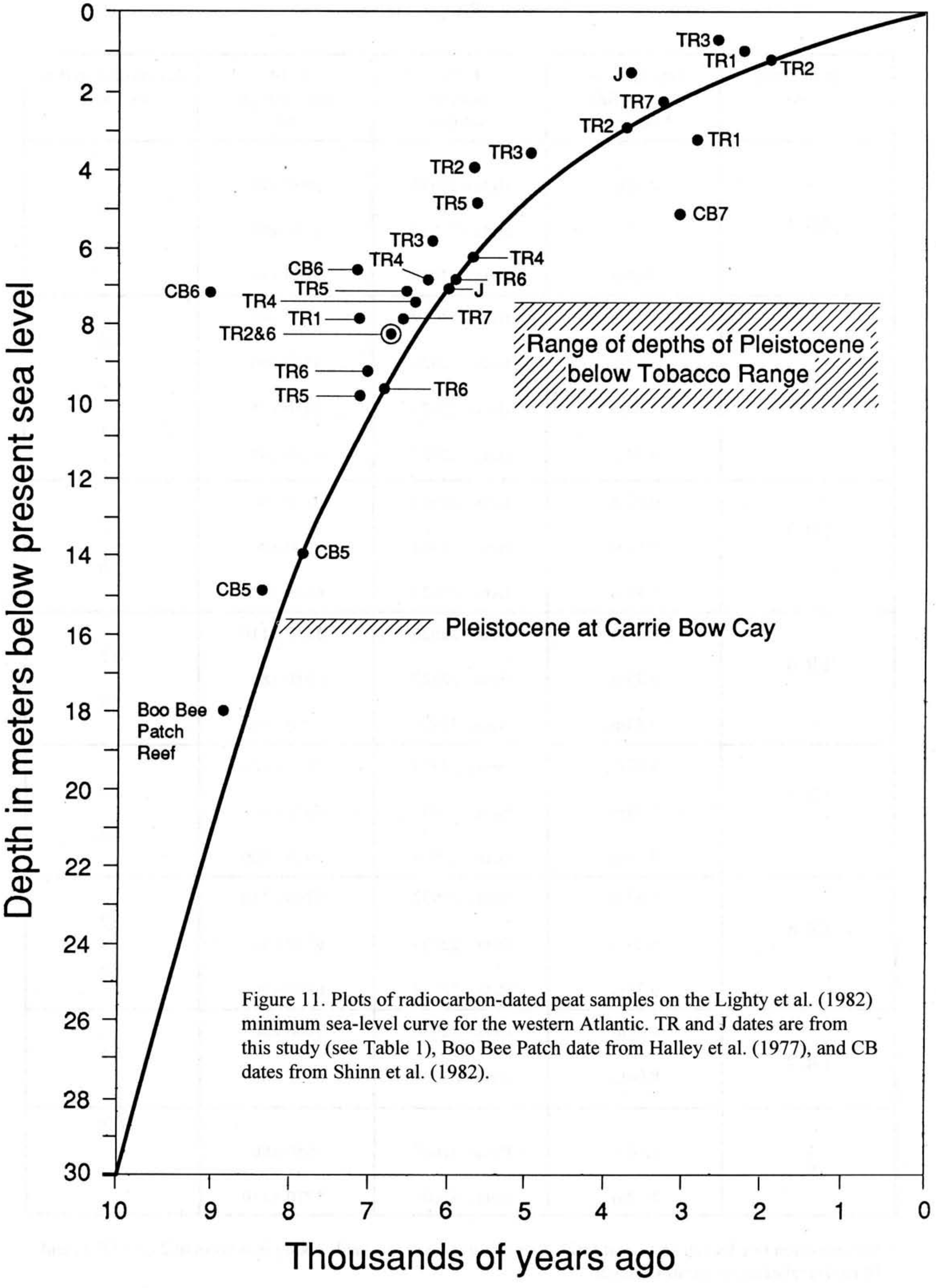

Figure 11. Plots of radiocarbon-dated peat samples on the Lighty et al. (1982) minimum sea-level curve for the western Atlantic. TR and J dates are from this study (see Table 1), Boo Bee Patch date from Halley et al. (1977), and CB dates from Shinn et al. (1982).

deeper areas of the lagoon became submerged by the rising seas, but others survived to flourish along the mainland coast and others on areas of high Pleistocene relief.

In the Tobacco Range area, with the decrease in the rate of sea-level rise about 3000 yrs B.P. to less than 1 m/1000 yrs (Fig.11), the peat accumulations became more stabilized resulting in the subsidence of mature deposits (Cameron and Palmer, this volume) and erosion of island shores with a reduction in the size of living mangrove cover. Consequently, relict peat was left stranded on the sea floor off most of the largest (northeastern) island of Tobacco Range. At present, the east coast is slowly accreting windward with the vegetation (mostly the red mangrove *Rhizophora mangle*) growing over debris and mud that is collecting along this coastline (Fig.12). In contrast, the leeward west coast is being actively eroded (Woodroffe, 1995, this volume), primarily during winter storms from the northwest, with the result that there is very little sediment overlying the submerged peat surface along this coast and the roots of mangroves and coconut palms (*Cocos nucifera*) are being actively undercut (Fig.13).

Basal Muds

The basal muds found in each vibracore and in sediment-probe samples commonly contain rock fragments of the Pleistocene limestone that lies directly below these muds (Fig.6). Similar basal mud deposits have been reported from below peat from northern Belize--" basal clay unit" (High, 1975, p.84) and "basal clay" (Ebanks, 1975, p.270). Similar basal muds were also recovered in four sediment cores collected around a small patch reef near Wee Wee Cay--"terrigenous clay" (Halley et al., 1977, p.32).

The Tobacco Range basal muds, which contained a complex mixture of calcareous mud, non-carbonate clays, quartz, peat, fragments of limestone, and Holocene carbonate skeletal debris, appear to be a reworked residual soil that formed on the subaerially exposed and weathered Pleistocene limestone surface. High (1975) considered the basal clay in northern Belize to be a coastal marsh deposit associated with a residual soil. His deposits, however, showed a "lack of shell material" (High, 1975, p.85) and an "abundance of montmorillonite". Montmorillonite settles rapidly from the water column in comparison to other clay minerals (Pierce and Siegel, 1979) and is commonly a dominant constituent of nearshore clay assemblages.This abundance of montmorillonite and absence of carbonate skeletal debris contrasts with Tobacco Range muds that contained skeletal fragments, notably marine molluscs and echinoids, and are dominated by kaolinite/chlorite clay minerals (Fig.10). Both of these characteristics suggest a more open-water influence on the development and reworking of residual soil at Tobacco Range in comparison to the inshore coastal deposits reported by High (1975) and Ebanks (1975) in northern Belize.

Slumping

The two vibracores (TR1 and TR2), on the west coast and adjacent to the fracturing and slumping, contained very long basal intervals of over 5 m of fine-fibered peat (Fig.6), which appears to outcrop in the fractured wall exposures. It is this easily erodible fine-fibered peat, exposed to oxidation, gravity flow and bottom-currents (Littler et al., 1995, this volume) that results in an undercutting of the more coherent upper sections of broad-fibered peat. These processes of undermining the overlying peat deposits could have been initiated and subsequently enhanced by forces associated with severe storms and earthquakes (Littler

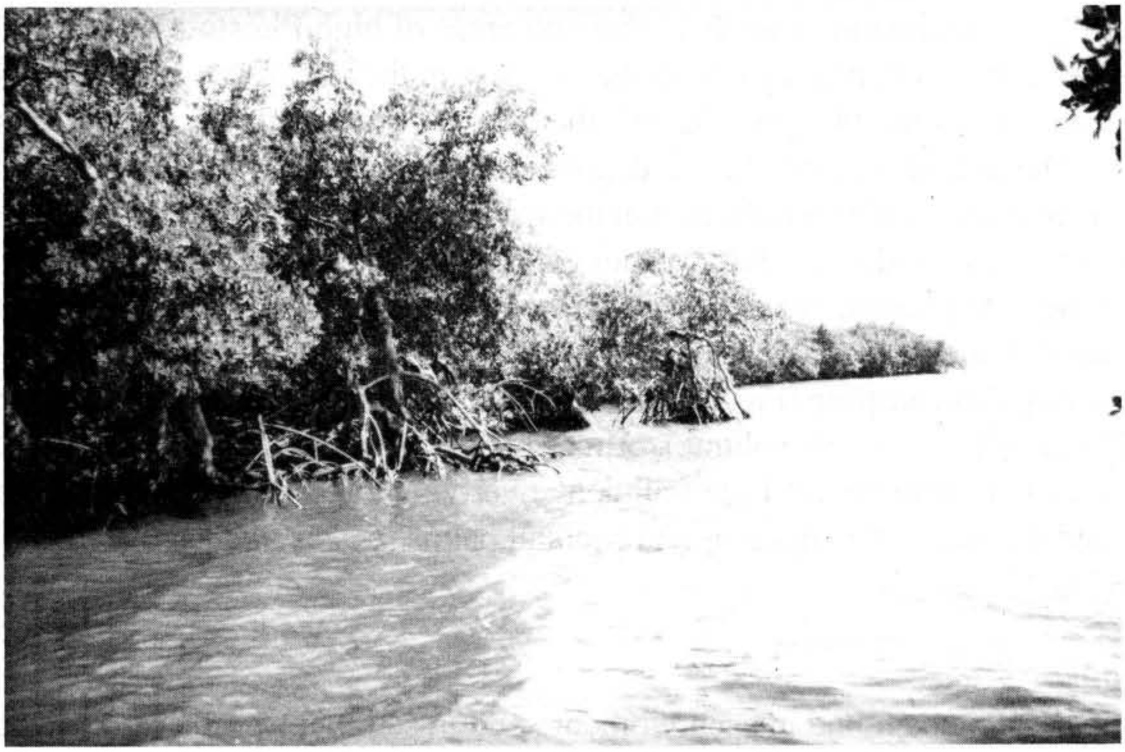

Figure 12. A thick growth of mostly red mangove(*Rhizophora mangle*) overgrowing sediments accumulating along the muddy windward east coast of the northeast island of Tobacco Range.

Figure 13. Active erosion along the west coast of the northeast island of Tobacco Range is indicated by the thin sediment cover on stranded peat (in foreground) and exposed roots of coconut palms (*Cocos nucifera*).

et al., this volume). This undermining has resulted in a fracturing of the submerged peat and slumping off of large blocks of peat into a watery muddy matrix of the fine-fibered peat (Fig.14).

Figure 14. Slump blocks of broad-fibered peat(with *Thalassia* still growing on their upper surfaces) partially buried in a slurry of fine-fibered peat and scattered carbonate sediments.

A Belize Sea–Level Curve

A plot of the radiocarbon dates of peat from this study along with peat dates from other lagoon cores in this area of Belize (Halley et al., 1977; Shinn et al., 1982) confirmed that the *Acropora palmata* minimum sea-level curve for the western Atlantic (Lighty et al., 1982) is valid for the general region of Belize (Fig.11). Almost all of the peat dates plotted on this sea-level curve or within a 3 m envelope above it -- including the dates from the area of recent slumping. Indeed mangrove dates should plot above a sea-level curve that is based on shallow-water coral radiocarbon dates and the peat dates of this study provide an upper mangrove limit for this minimum sea-level curve.

There are, however, three notable examples where the peat dates did not plot close to this sea-level curve (Fig.11). One date of 8808±600 yrs B.P. for CB6 at 7.32 m (Shinn et al., 1982) was much older than expected. This peat was associated with terrigenous sediments and could have been contaminated with older debris. On the other hand, the two samples that plot below the curve, CB7 with a date of 2861±190 yrs B.P. at a depth of 5.22 m (Shinn et al., 1982) and the TR1 date of 2670±90 yrs B.P. at a depth of 3.30 m could both have been contaminated by younger root penetrations.

These findings contrast sharply with the Belize sea-level curve proposed by Westphall (1986), which was based on published peat dates (Purdy, 1974; Halley et al., 1977; and Shinn et al., 1982) and indicates an abrupt decrease in the rate of sea-level rise about 5500 years ago at a depth of 1 m. The data that supports the shallow-water depths, however, are highly questionable and are not all derived from Purdy (1974) as indicated by Westphall. Indeed it appears that most of these dates came from Ebanks (1967) and were probably obtained from reworked or freshwater peats on the Shallow Pleistocene shelf in nothern Belize. The dates in Figure 8 follow the trend of the western Atlantic minimum sea-level curve and show no evidence for water depths as shallow as 1m about 5000 years ago. It is highly unfortunate that the Westphall sea-level curve has been introduced into the literature as evidence that sea-level curves of some Atlantic sites are comparable to those of Australia and the central Pacific (Davies and Montaggioni, 1985; Woodroffe, 1988).

CONCLUSIONS

1. The mangrove island complex of Tobacco Range was initiated as a mangrove community on a weathered Pleistocene limestone surface about 7000 years ago. The initial accumulation of mangrove peat has kept pace with the rising sea levels of the Holocene transgression to form the present-day island systems with peat sections of up to10 m thick. With the marked decrease in the rate of sea-level rise over the last 3000 years, there has been a stabilization in the growth of these mangrove islands, which has resulted in considerable erosion and reduction in size of the living mangrove cover.

2. The thin basal mud sections below the peat at Tobacco Range represent an open-water reworked residual soil that covers the eroded Pleistocene limestone.

3. Slumping off the west coast of Tobacco Range appears to be related to the removal of readibly erodable fine-fibered peat that is exposed below the upper sections of more resistant broad-fibered peat.

4. Radiocarbon dates of mangrove peat from Tobacco Range and surrounding areas confirm that the minimum sea-level curve for the western Atlantic (Lighty et al., 1982) is applicable to the Belize region.

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