

ATOLL RESEARCH BULLETIN

NO. 426

**INTRODUCTION TO THE BIOLOGY AND GEOLOGY OF
TOBACCO RANGE, BELIZE, C.A.**

BY

M.M. LITTLER, D.S. LITTLER, AND I.G. MACINTYRE

**ISSUED BY
NATIONAL MUSEUM OF NATURAL HISTORY
SMITHSONIAN INSTITUTION
WASHINGTON, D.C., U.S.A.
AUGUST 1995**



Figure 1. Oblique wide-angle aerial photograph of Tobacco Range, looking from the northeast toward the southwest.

INTRODUCTION TO THE BIOLOGY AND GEOLOGY OF TOBACCO RANGE, BELIZE, C.A.

BY

Mark M. Littler¹, Diane S. Littler¹, and Ian G. Macintyre²

The Belize Barrier Reef complex varies from 10 to 32 km in width and is over 200 km in length. The complex is composed of diverse intertidal and subtidal barrier and patch reef zones, three large atolls, vast lagoonal seagrass beds, and hundreds of mangrove islands. The Barrier Reef complex is established on the Yucatan Block, an almost continuous series of limestone deposits formed during the Cretaceous to Pliocene (Miller and Macintyre, 1977). During the Pliocene, the Yucatan Block was tilted northward to form the Campeche Bank, whereas a set of north-northwest trending faults produced submarine escarpments on the eastern margin, influencing the geomorphology of the Belize continental shelf.

The Belize Barrier Reef runs approximately parallel to the faults, and raised blocks formed during the Pleistocene on the continental shelf have provided critical shallow-water foundations for reef-forming organisms (Purdy, 1974). Extensive mangrove communities also developed on these elevated Pleistocene reliefs in low energy environments behind the active margin of the Barrier Reef (Chapman, 1976; Woodroffe, 1983) as the shelf became flooded by the rising seas of the Holocene transgression. Most of these mangrove communities ultimately were drowned and subsequently buried by calcareous marine sediments, except in the areas of higher Pleistocene relief where mangrove systems such as Tobacco Range have traced the rising sea level for the past 7,000 to 9,000 yrs (Macintyre et al., 1995, this volume).

¹ Department of Botany, National Museum of Natural History, MRC#166, Smithsonian Institution, Washington, D.C. 20560, U.S.A.

² Department of Paleobiology, National Museum of Natural History, MRC#125, Smithsonian Institution, Washington, D.C. 20560, U.S.A.

Tobacco Range is a roughly oval (atoll-like) group of mangrove islands (Fig. 1) surrounding a central 2 m-deep lagoon on the outer platform of the Belize Barrier Reef about 2 km west of the Barrier Reef crest. The Tobacco Range mangrove system is approximately 1.7 km wide and 4 km long with the largest island lying at the northeast of the complex. Two long narrow islands to the southeast and southwest complete the lagoonal margin (Fig. 1).

The climate of the Tobacco Range region of the Belize barrier reef is drier than the coastal mainland (Woodroffe, 1995, this volume). The Dangriga coastline to the west receives more than 2000 mm of rainfall per year, mostly during June to October. Nearby, Carrie Bow Cay receives an annual rainfall of about half that at Dangriga (Rützler and Ferraris, 1982). The prevailing winds are northeast tradewinds, although there are times during the dry season when low pressure systems with associated fronts bring northwest winds that are often accompanied by strong waves (Perkins, 1983). The area also is vulnerable to hurricanes during July to October, and was devastated by the passage of Hurricane Hattie in 1961 (Stoddart, 1963, 1974).

Our attention became focused on the atoll-like Tobacco Range mangrove group in February 1986 when a 0.5 km-wide by 2.0 km-long region of fractured and slumped fossil peat was discovered (Littler et al., 1995, this volume) off the west coast of the northeastern island. Sediment-core samples from seven vibracores and ten soil-sampling probes across the northeastern island indicated (Macintyre et al., 1995, this volume) that this ecosystem has been dominated by mangrove communities 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, coarse-fibered peat with conspicuous plant fragments, which overlie a partially decomposed dense fine-fibered peat with almost no recognizable macroscopic plant remains. The basal muds, which consist of a mixture of calcareous and non-carbonate sediments, are probably a reworked wetland soil. Peat-depositing mangrove communities became established on this Pleistocene limestone area of high topographic relief about 7,000 yrs B.P. and accumulated peat at a mean rate of 4.3 m per millennium, which was sufficient to keep pace with the rising sea levels during the Holocene transgression. Radiocarbon dates of Tobacco Range peat samples confirm (Macintyre et al., 1995, this volume) that the late Holocene history of sea-level rise in Belize is consistent with that reported for other western Atlantic areas.

With the decrease in the rate of sea-level rise at about 3000 yrs B.P. to just under 1 m per millennium, the peat accumulations stabilized resulting in the net erosion of island shores with a concomitant reduction in the area of living mangrove cover.

Consequently, a bank of relict peat was left stranded on the seafloor off the largest (northeastern) island of Tobacco Range. At present, the east coast of this island is slowly accreting windward with the vegetation (mostly the red mangrove *Rhizophora mangle*) growing over water-borne particulate matter that is being deposited along this coastline. In contrast, the leeward western shoreline is being actively eroded (Woodroffe, 1995, this volume). *Avicennia* woodland is now exposed along the broad west fringe of the range, fronted by the eroded peat surface. As mentioned, this area is subject to substantial swell under northwesterly winds and will continue to retreat (Woodroffe, 1995, this volume). The entire western limb of the southwestern island of Tobacco Range also has undergone retreat; there are numerous dead *Avicennia* stumps, perhaps initially damaged by Hurricane Hattie. Locally, *Rhizophora* seedlings have established on the lagoonward shore of this part of the range, but their establishment probably is insufficient to reverse the general regression.

Different plant communities have flourished throughout Tobacco Range's habitats and history and include (Woodroffe, 1995, this volume): *Avicennia* woodland (up to 6-8 m high), mixed *Avicennia* and *Rhizophora* open woodlands (> 4 m high), *Rhizophora* woodlands (> 4 m high), *Rhizophora* thickets (2-4 m high), *Rhizophora* scrub lands (< 2 m high), and unvegetated flats. *Rhizophora* thickets are characteristic of the outer margins of most of the islands. *Avicennia* woodlands typically occur in the center of islands, generally on substrates that are less frequently flooded than those beneath *Rhizophora*; however, to the northwest *Avicennia* woodlands have been exposed on the margin by extensive erosion. Mixed *Avicennia* and *Rhizophora* open woodlands are found throughout most of the island interiors and are transitional between *Rhizophora*-dominated and *Avicennia*-dominated vegetational types. *Rhizophora* scrub lands also occur near the centers of islands and, except where bisected by creeks, inhabit areas that appear to have been stripped of previous vegetation relatively recently.

Such vegetational differences partially account for the heterogeneity of ash and trace element contents found in the various fossil peat cores taken from the northeast island. The core samples showed alternation of layers of low and high ash content, which was interpreted (Cameron and Palmer, 1995, this volume) as reflective of cycles of rapid growth (low ash) versus periods of mangrove destruction and decomposition (high ash). The average ash contents in the deeper more-decomposed peat samples are generally greater than in the shallower coarse-fibered peat; also, peat cores from the interior of the island tend to be higher in ash than those at the edges of the island. The concentrations of some elements in the Tobacco Range peats are strikingly similar (Cameron and Palmer, 1995, this volume) to those in freshwater peats of Sumatra. The elements S, Ba, Na, Br, and Sr, but not Rb, are significantly higher in the Tobacco Range peats than in the Indonesian peats, which suggests that most were added to the dead plant remains during the

depositional process and were not accumulated during active growth. Most of the mean concentrations of other elements also are similar to the Indonesian peats within a factor of two. This probably indicates that the Tobacco Range peats like the Sumatra deposits have had a terrestrial input of elements from water-borne sediments, volcanic dust, and pumice, which even today wash up on the shores.

Littler et al. (1995, this volume) posited that hydrostatic intrusion has led to aerobic decomposition and erosion of the thick sections of fine-fibered peat overlying the Pleistocene carbonate sea-floor base off the west coast of the northeast island. This has caused an extensive undercutting of the more-resistant overlying coarse-fibered peat and, hypothetically, has produced the extensive fracturing and slumping of the peat deposits; i.e., the spectacular sea-floor relief observed (see Frontispiece, this volume). This unusual marine landscape consists of vertical submarine peat exposures, tilted slumping blocks of fossil peat, deep holes, and long narrow fractures. The upper edges of the exposed vertical walls are composed of a 10 to 20 cm-thick veneer of a living *Thalassia testudinum* community atop a 1 to 7 m-thick consolidated layer of fossil mangrove peat. This seagrass-dominated peat surface slopes westward to its point of lowest relief (<1.0 m thick, 300 to 500 m offshore) and contains poorly sorted sandy gravels and gravelly carbonate sands (mostly mollusc and foraminiferan fragments) on the unfractured surfaces, and muddy calcareous peat sediments within the fracture depressions (Littler et al., 1995, this volume). The breadth of the fractures varies from narrow fissures only 0.1 m in width to over 30 m across. Fractures nearest the island tend to be at right angles to the shoreline, dendritic or digital, and less weathered than those farther seaward. Fractures toward the northeast and southwest extreme ends of the system retain vertical or undercut walls up to 7-m thick along their entire perimeters (see Frontispiece, this volume), whereas the more central fractures tend to have collapsed outer walls with subdued weathered relief. Most of the slumped blocks contain sparse *T. testudinum* beds identifying their upper surfaces and have been tilted at chaotic angles ranging from horizontal to 35°. Multiple levels, platforms, and undercuts are conspicuous along most of the vertical walls revealing the preservation of a strongly bedded zonal pattern in the peat.

The Tobacco Range fracture zone has provided some unusual habitats for marine organisms (Littler et al., 1995, this volume). In general, the overall biota is sparse, consisting of typical members of the *Thalassia testudinum* seagrass community plus certain unusual elements. Sixty three species of marine macrophytes (61 algae and 2 vascular plants) were found (Littler, Littler, and Brooks, 1995, this volume) in the habitats within and surrounding the fractured peat zone. Of the macroalgae, 35 are Chlorophyta (greens), 22 Rhodophyta (reds), and 4 Phaeophyta (browns); 14 taxa are new records for Belize. The sedimentary bottoms of the fractures contain eight unique species, all of which are psammophytic Chlorophyta, not documented on the

vertical fracture walls or surrounding seagrass habitat. The fracture walls support 4 Chlorophyta and 2 Rhodophyta not collected in samples from the fracture bottoms or seagrass beds; whereas, the adjacent seagrass beds include 12 Rhodophyta and 3 Chlorophyta that did not occur in samples from the fractured peat habitats. Nine Chlorophyta, two Phaeophyta, and one Rhodophyta are common to all three habitat types. Between-fracture floristic differences are minor and related to the age and size of the fractures. Because of a conspicuous reduction in macrophytic cover and a shift to domination by slower-growing calcareous rhizophytic forms, Littler, Littler, and Brooks (1995, this volume) hypothesized that the fracturing process has resulted in a considerable loss to total ecosystem primary productivity. The unusual elements of the fractures appear to be in response to: (1) new spatial heterogeneity adding increased surface area and shelter, (2) diverse sedimentary substrates utilized by psammobiotic forms, and (3) a trapping effect that concentrates large mobile gastropods. This last occurrence has resulted in a phenomenon termed "interior halos" of barren sediments, since the physical bioturbation (plowing action) by these large animals apparently has eliminated rooted plant life and other sessile organisms along the perimeters of the slump depressions at the bases of the vertical peat walls.

The peat slurry between the slumped blocks of coarse-fibered peat at the innermost limits of slumping, the presence of escaping stained humic waters in conjunction with the undercut peat exposures at the lowest depositional levels, the partially decomposed sections of fine-fibered peat found in cores adjacent to slumping, and the interconnected dendritic slump patterns all suggest (Littler et al., 1995, this volume) that fracturing and slumping may be related to aerobic decomposition following hydrostatic exposure of the underlying fine-fibered peat. The subdued relief of the peat blocks (now overgrown by seagrass) in the broad depressions at the outer limits of slumping indicate that collapsing of submerged peat has been taking place for centuries and possibly millennia. The isolated fracture areas eventually become interconnected by additional dendritic branches, which predictably will continue to slump to form broader slump depressions.

ACKNOWLEDGEMENTS

We gratefully acknowledge Klaus Rützler for overall programmatic support and management of the Smithsonian Institution's Carrie Bow Cay facility. Fieldwork for this research was supported by the National Museum of Natural History's Caribbean Coral Reef Ecosystem Program (CCRE Contribution Number 462). Much of the laboratory work-up was supported by the Smithsonian Marine Station at Link Port (SMSLP Contribution Number 385).

REFERENCES

- Cameron, C.C. and C.A. Palmer. 1995. The Mangrove Peat of the Tobacco Range Islands, Belize Barrier Reef, Central America. *Atoll Research Bulletin*, 431: 1-32.
- Chapman, V.J. 1976. Mangrove Vegetation. Vaduz, Germany: J. Cramer Publications, pp. 1-447.
- Littler, D.S., M.M. Littler and B.L. Brooks. 1995. Marine Algae and Seagrasses from the Tobacco Range Fracture Zone, Belize, C.A. *Atoll Research Bulletin*, 429: 1-43.
- Littler, M.M., D.S. Littler, I.G. Macintyre, B.L. Brooks, P.R. Taylor and B.E. Lapointe. 1995. The Tobacco Range Fracture Zone, Belize, C.A.: a Unique System of Slumped Mangrove Peat. *Atoll Research Bulletin*, 428: 1-31.
- Macintyre, I.G., M.M. Littler and D.S. Littler. 1995. Holocene History of Tobacco Range, Belize, Central America. *Atoll Research Bulletin*, 430: 1-18.
- Miller, J.A. and I.G. Macintyre. 1977. Field Guidebook to the Reefs of Belize. Third Intern. Symp. Coral Reefs. Fisher Island, Miami Beach, Florida: Univ. Miami, pp. 1-36.
- Perkins, J.S. 1983. The Belize Barrier Reef Ecosystem: an Assessment of Its Resources, Conservation Status and Management. *New York Zoological Society Report*, 189 pp.
- Purdy, E.G. 1974. Karst-Determined Facies Patterns in British Honduras: Holocene Carbonate Sedimentation Model. *The American Association of Petroleum and Geologists Bulletin*, 58(5): 825-855.
- Rützler, K. and J.D. Ferraris. 1982. Terrestrial Environment and Climate, Carrie Bow Cay, Belize. In K. Rützler and I.G. Macintyre, eds. The Atlantic Barrier Reef Ecosystem at Carrie Bow Cay, Belize I: Structure and Communities. *Smithsonian Contributions to Marine Science*, 12: 77-91.
- Stoddart, D.R. 1963. Effects of Hurricane Hattie on the British Honduras Reefs and Cays, October 30-31, 1961. *Atoll Research Bulletin*, 95: 1-142.
- Stoddart, D.R. 1974. Post-Hurricane Changes on the British Honduras Reefs: Resurvey of 1972. *Proceedings of the 2nd International Coral Reef Symposium*, pp. 473-483.
- Woodroffe, C.D. 1983. The Development of Mangroves from a Geological Perspective. Pages 1-17 In H.J. Teas, ed., *Biology and Ecology of Mangroves*. The Hague: Dr. W. Junk.
- Woodroffe, C.D. 1995. Mangrove Vegetation of Tobacco Range and Nearby Mangrove Ranges, Central Belize Barrier Reef. *Atoll Research Bulletin*, 427: 1-29.



Aerial view eastward toward the Tobacco Range fracture zone and the adjacent northeast mangrove island. The small white object in the central fracture depression (center of photograph) is the 5-m long inflatable research boat used in the study.