ATOLL RESEARCH BULLETIN

NO. 431

THE MANGROVE PEAT OF THE TOBACCO RANGE ISLANDS, BELIZE BARRIER REEF, CENTRAL AMERICA

BY

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

Cornelia C. Cameron, Tobacco Range
March 24, 1989

CORNELIA CLERMONT CAMERON (1911-1994)

Cornelia Cameron, an internationally recognized peat geologist, died of cancer at age 83 on August 5, 1994, at her home in Winchester Virginia. Her work helped elevate the study of peat and its resource potential to a respected scientific discipline. Cornelia received her B.A. and M.S. degrees in botany and a Ph.D. in geology (with emphasis in geomorphology) from the University of Iowa. She worked in the earth sciences sections in museums in New York and Missouri from 1940 to 1942, and then taught geology at Stephens College in Columbia, Missouri, for 9 years.

From 1951 until her death in 1994, she worked for the U.S. Geological Survey. Her early U.S. Geological Survey work was in the Military Geology Branch, where she did terrain analysis based on literature, photo interpretation and field studies; she was senior author of a 262-page Army Field Manual on terrain intelligence. From 1953 to 1964, she did field work in Japan, Korea, Taiwan, Nigeria and the Caribbean Islands, turning out 50 reports on water resources and engineering construction and foundations. In Korea she served as an engineering geology consultant to the United Nations forces.

Her interest in peat started after the Atlantic coastal storm of March, 1962, which greatly accelerated normal beach erosion. The surfline at Dewey Beach, Delaware, exposed extensive peat formations and tree stumps. The geologic study and carbon- 14 dating of the peat collected by Cornelia indicated that it had been part of the landward side of the lagoon between the barrier island and the mainland forest only 200 years earlier. Cornelia showed by this study that relative sea level rise had a faster rate than before realized. She then considered other facts to be gained from the study of peat, including correlation of vegetation with satellite images, analysis of clues to surrounding mineral deposits, and the resource potential of growing vs. static peat areas. She persuaded the U.S. Geological Survey to recognize the need for research on peat and began with the peat resources of Appalachia in 1965. In time she became known worldwide as a leading authority on peat resources and their quality. Her improvements in the McCaully sampler for measuring the stratigraphy of peat deposits changed the technology of peat studies. She was influential in shifting the peat industry from its emphasis on fuel use to agricultural purposes as well. From an initial focus on sphagnum peat, she proceeded to study all types of peat worldwide. In recent years, she carried out studies at the request of the government of Indonesia in Sumatra and Kalimantan (Borneo).

Of the more than 110 publications in her bibliography, Dr. Cameron's most notable include one of the first geology textbooks in this country that relates geology to society, Earth, Sky and Human Affairs, 1946, published by Stephens College. More recently, her 1983 paper on variations in mineral content of peat, a 1984 paper on the relationship between geology of peat deposits and their exploration and economic consideration, and a 5-volume set on the peat resources of Maine have assured Dr. Cameron's position as the world's foremost expert on peat deposits.

Cornelia's work received much recognition. She was a member of Sigma Xi. In 1969 she became the peat commodity geologist for the U.S. Geological Survey. In 1984, the legislature of the State of Maine voted a commendation in recognition of Cornelia's vital role in delineating peat as an important resource of that state. She also received letters of appreciation from the governor of Maine and its legislature for her outstanding work in

Maine, and from the Roosevelt-Campobello International Park Commission in Maine where she was called on to map the peatlands. In 1977, she received the Meritorious Service Award of the Department of Interior and, in 1986, she received the Distinguished Service Award of the U.S. Department of the Interior. In 1990, she received the Department of the Interior's Public Service Recognition Award as well as the Distinguished Alumni Achievement Award of the University of Iowa. She also served for 13 years as Vice Chairman of the International Peat Society.

Both of Cornelia's parents were botanists, with B.A. and M.A. degrees. While her mother completed work for a Ph.D., her father was a professor of natural sciences and agriculture in Missouri, and did much lecturing and photography in these fields, especially on the Chautauqua circuit. They returned to the University of Iowa, where both had studied, but her father died as a result of the influenza epidemic of 1918, when Comelia and her brother were small children. Her mother, who had taught in the Iowa City schools for several years, then supported the family by operating a farm they had purchased. When Cornelia went to work with the U.S. Geological Survey her mother lived with her. Her mother accompanied Cornelia on her field work until her mother was 103 years old. Her mother's botanical work was essential to coordinating the ground studies with satellite images.

Field geologists benefit from an awareness of the local people and sociology. Cornelia and her mother mastered this skill in many situations. In many areas around the world, people were leery of government representatives, and care was needed in approaching the local people. Cornelia's mother often maneuvered the first contacts, winning everyone with her gracious manner, and introducing Cornelia to the local people, which allowed Cornelia information she would never have been able to obtain in other ways. One day when Cornelia was in Cuba before the Bay of Pigs invasion, she was working in the field when her mother, who had stayed behind in the car, was approached by a truck full of guerrillas. Her mother simply charmed the guerrillas by telling them that she was a Canadian tourist, and they drove off.

Cornelia was full of surprises. She always wore khakis in the field and was working in Japan when a general gave a formal dinner. To everyone's astonishment, Cornelia appeared in a satin gown with matching elbow-length gloves. When asked about it later, she replied that one had to be prepared for proper occasions.

Cornelia was actively working until just before her death. She completed a full season of field work in Oregon and Wisconsin in 1993 and was involved in the geochemistry of peat deposits in the Midwest as part of a project on herbicides in soil and groundwater. She was also active in a coring study as part of the Great Lakes Wetlands program. Her final manuscript follows in this volume. In the end, she was concerned about all the things she had yet to do, but we who were touched by her life will always appreciate all the wonderful things she accomplished.

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THE MANGROVE PEAT OF THE TOBACCO RANGE ISLANDS, BELIZE BARRIER REEF, CENTRAL AMERICA

BY

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ABSTRACT

Core samples of Holocene mangrove peat were collected onshore and offshore of the north island of Tobacco Range to analyze the peat texture and composition. These characteristics of the peat were then related to the geological history of this island and to the flora that formed it. Chemical data determined by instrumental neutron activation analysis as well as ultimate and proximate analysis suggest that these elements have a mainland origin from volcanic ash or possibly other sources. The heterogeneity of the ash and trace element content in the peats may be accounted for by sea level changes, rate of plant growth and decay, and types of vegetation.

INTRODUCTION

Tobacco Range is a circular group of mangrove islands surrounding a central lagoon on the outer platform of the Belize Barrier Reef about 2 km west of Tobacco Cay in the Caribbean Sea (Fig. 1). The mangrove islands in this area are underlain by mangrove peat, which rests on limestone bedrock of Pleistocene age (Macintyre et al.,1995, this volume).

Tobacco Range is about 5 km long and 2 km wide. The largest island, at the north, which contains small shallow lagoons and tidal waterways, is the subject of this study (Fig. 2). Two long narrow islands to the south and a series of smaller islands complete the lagoonal fringe. Cores taken at the north island show a maximum thickness of 10 m of peat developed chiefly from plants of red and black mangrove communities. Peat also extends below the ocean surface on either side of Tobacco Range The maximum elevation of the peat surface on the north island is only 20 cm above mean sea level (MSL). The purpose of this study was to examine and characterize the subsurface peat strata from a transect series of cores used for radiocarbon dating of the Holocene history of the Tobacco Range (Macintyre et al., 1995, this volume).

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Manuscript received 19 June 1995; revised 14 August 1995

METHODS

Cores were taken along a northwest-southeast transect (Figs. 2 and 3) of the north island to define the characteristics of the subsurface. A vibracore was used to obtain core TR1 onshore and all cores offshore including core TR3 off the east coast. All cores were described and sampled in the laboratory after transport in boxes. Some moisture was lost in the process. Later, hand-operated Macaulay and Davis peat samplers were used on land and off the east coast to collect the remainder of the cores. These cores were described and sampled in the field, and transported to the laboratory in moisture-proof containers.

The pH of all samples was measured in the laboratory and ash content was recorded as percent dry weight. The dry weight was obtained by heating the sample to 110° C after air drying for several weeks. The ash content represents inorganic material remaining after ignition at 550°C for 24 h. Element content was obtained by instrumental neutron activation analysis at the U.S. Geological Survey from representative splits of each sample. In addition, a few samples were analyzed by Dickinson Laboratories, Inc.[1] for proximate and ultimate analyses, BTU, and forms of sulfur.

RESULTS

The Geological Setting of the Peat

The Yucatan Block consists of an almost continuous sequence of Cretaceous to Pliocene shallow water limestone deposits. During the Pliocene the entire Yucatan block, upon which Belize lies, was tilted northward to form the present Campeche Bank. A set of north-northwest-trending normal faults formed submarine escarpments on the east. These faults influence the shape and bathymetry of the Belize shelf. An echelon parallelism in many of the linear segments of the coastline, the shelf-edge, and the offshore atolls, suggests fault control by known inland surface-expressed faults (Miller and Macintyre, 1977).

The Belize Barrier Reef is also roughly parallel to the strike of the normal faults. The upthrown blocks apparently provided a shallow water foundation for initial coral development during the Pleistocene. Reefs appear to have formed in areas of slow but continual subsidence, a periodic condition typical of Pleistocene time and continuing into the Holocene (Adey, et al., 1977). Meanwhile, mangrove peat was also accumulating in an ever thickening layer.

The peat collected in cores along the study transect (Fig. 3) rests on or is close to the bedrock. Because mangroves can only initiate growth in sheltered places, the initial mangrove seedlings took root in the low-energy environment behind the active coral reef where they were protected from the full force of ocean waves (Chapman, 1976; Woodroffe, 1983). During this time of initial settlement, the sea floor was covered with a residual soil and carbonate sand from leached limestone that was subaerially exposed during the

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[1]Any use of trade , product, or firm names is for descriptive purposes only and does not constitute endorsement by the U. S. Government..

Pleistocene. Except for a thin, exposed pavement directly shoreward of the reef crest, all reef flat and lagoonal shallow sediments, over a distance of at least 24 km, were uncemented, which permitted the rooting of mangroves.

Radiocarbon peat dates from these cores indicate that the Tobacco Range mangroves were established on or near the Pleistocene limestone surface at least 7,000 years ago (Macintyre et al., 1995, this volume). At this time, the shorelines of land areas were far westward beyond the present shorelines of Tobacco Range. The dates shown on the cores along the northwest-southeast traverse (Fig. 3) plot on or within 3 m above the minimum sea-level curve for the Caribbean and tropical western Atlantic Ocean based on growth of a shallow-water coral Acropora palmata reef framework (Macintyre et al., 1995, this volume)

Mangrove communities have traced the rising sea levels for the past 9,000 years and today are surviving on the high Pleistocene relief of the Tobacco Range. The rising sea level during the Holocene transgression flooded many mangrove communities and covered the forest floor west of Tobacco Range to depths of 6 m. The mangroves to the east, however, were established on a shallower Pleistocene surface and continued to grow while sea level was rising more slowly. Thus, peat accumulation could keep pace with rising sea level, although not at a regular rate in every locality (see Macintyre et al., 1995, this volume). During the past 7,000 years, peat accumulated to a maximum thickness of 10 m in the interior of the north island as measured at core site F.

Peat

The total land surface covered by peat to a depth of more than 30 cm is estimated by Kivinen and Pakarinen (1980) to be approximately 500 million hectares. Geologically, peat is very young and belongs almost entirely to the Quaternary. The unburied deposits are mostly of Holocene age. Although peat deposits of varying thickness and extent are common and widespread in many types of geologic settings throughout the world, mangrove peat is restricted to mangrove swamps in salt and brackish water along tropical and subtropical coastlines and islands. Mangrove swamps are located mostly between latitudes 25°N and 25°S, below the limits of freezing weather (Mitsch and Gosselink, 1986). Mangrove communities can develop only where there is adequate protection from wave action (Chapman, 1976). Their growth is restricted to the intertidal zones which are narrow at Tobacco Range. At Carrie Bow Cay, about 10 km away, the mean tidal range is only 15 cm. Tides are of the mixed semidiurnal type (Kjerfve et al., 1982). This restricted tidal range makes the mangrove peat highly useful for dating relative sea-level rise.

Peat consists of partly decayed plant matter, inorganic minerals, and water in varying proportions. The American Society for Testing and Materials (ASTM, 1969) defines quality standards for commercial peat that generally apply to that of fresh water origin. Accordingly, a "peat" must contain less than 25 percent dry weight inorganic material or ash to be used for agricultural or horticultural purposes. Peat formed in brackish or salt water contains soluble salts that increase ash content. In this paper, peat containing less than 31 or 32 percent ash content is considered "peat." "Muddy peat" contains roughly 32 to 75 percent ash content, and "peaty mud" greater than 75 percent.

Major differences in peat accumulation result from the variety of plants from which peat is formed, the relationship of the deposits to the water table regime, and the degree to which part of the peat has decayed or been removed by fire or storms (Cameron 1988). These factors are affected by climate, ground water level, and surface topography of the wetland. The inorganic components of peat include both minerals from the substrate and elements absorbed by roots from ground water or surface water. Also, minerals are introduced to the peat-forming environment as suspended detritus, volcanic ash, or are precipitated from solution. The peat of Tobacco Range derived its inorganic components mostly from sea water, and from the limestone bedrock and residual soil in basal sections. Both the organic and inorganic components of peat are affected by the chemistry and microbial activity of the depositional systems.

Several factors are known to govern peat quality irrespective of inorganic components. Fluctuating water tables within the deposit can permit oxygenation of the organic material, thereby allowing aerobic microbes to decompose plant fibers. Where water tables remain high, peat accumulates faster than it decays and builds up the deposit. Low ash peat accumulation can continue until the water table declines during dry weather or through drainage changes cause decay which raises the ash content and destroys fibers. The surface of the peat is thereby lowered.

If the rate of mangrove peat accumulation is faster than the rate of sea level rise, the peat may reach an elevation at the highest level of the tidal range. Nutrients to the roots are cut off at this boundary and decay sets in, and the peat surface is subsequently lowered by erosion to form a depression. In the depression, a pool may form that may become part of a tidal waterway in which new young trees take root and thrive. As sea level transgression continues, the cycle begins anew with young thriving mangroves and relatively rapid low ash peat accumulation in former depressions.

Physiography Along the Cored Traverse

Interpretation of the environmental history recorded by the peat stratigraphy of Tobacco Range requires knowledge of the physiography of the modern peat surface. The surface of the north island is marked by flats, low rises, ponds, and tidal waterways. Mangroves nourished by tidal water flourish and produce a biomass that is the source of peat and builds the peat surface at a rate faster than sea level rise. As noted earlier, uninterrupted peat may reach a height above the range of tidal nourishment where decomposition occurs; decomposition then exceeds accumulation, and the peat surface may subside to hold a pond within the tidal range. A new cycle may begin again. Hurricanes also cause interruptions in peat accumulation by removing vegetation and fostering decomposition of the peat surface. As the sea transgresses and the surface of the island of peat rises, layers having lower ash content represent relatively rapid mangrove growth. These alternate with layers of greater ash content that represent the materials of ponds and waterway bottoms and flat surfaces denuded by hurricanes. Alternation of layers of lower and greater ash content is shown by patterns in the cores (see Figs. 4, 5, 6, and 7).

Submerged slump blocks of peat occur in the cores collected from unstable mangrove environments. Fracture patterns occur where relatively fresh peat rests on partly decomposed peat muds. Littler et al., (1995, this volume) suggest that slumping occurred as a result of aerobic decomposition and bottom current erosion. During, periods of severe wave activity, blocks of submerged peat along the edge of the island slump down slope to become submerged in old fine fibered peat. The offshore cores, TR4 and TR6 (Fig. 3), are believed to contain anomalous peat talus broken from the sides of the island during severe wave action.

Vegetation Reflects the Modern Physiography

The vegetation types vary along the island transect (Figs. 2 and 8, Woodroffe, 1995, this volume). The types are distinct and can be recognized in cores because they represent environments that are repeated at least in part throughout the development of Tobacco Range. These vegetation types are distributed from core B on the east coast or windward side of the island across the length of the traverse to the western or leeward side at core TR1.

***Avicennia* Open Woodland and *Rhizophora* Woodland**

In the traverse that begins on the windward (eastern) side, a vegetation type classified as *Avicennia* open woodland with *Rhizophora* (Woodroffe, 1983) grows on a gentle rise above sea level. Red mangrove (*Rhizophora*) dominates this area. Scattered black mangrove *Avicennia* also grows but is shorter and less robust than in more protected inland areas. Marsh grass and sprawling woody vines are common at the core B location, where little if any peat is accumulating. In addition to decomposition, fine-grained sediment washed over the area contributed to the high ash content in the upper part of core B (Fig. 3).

Unvegetated Flats

The adjacent "unvegetated flats" sampled in cores D and E are topographically lower in height than the site at core B (Fig. 8). Vegetation apparently had been killed by flooding, possibly during a hurricane. The flats are now covered by a regrowth of red mangrove and Batis, a low shrub having fleshy leaves. Pools of stagnant water are juxtaposed with bare areas of fine and largely algal-derived surface sediments. Firm mangrove peat that lies below all of these flats suggests that the community is growing on a storm-eroded peat surface that undoubtedly is undergoing decomposition.

***Rhizophora* Woodland**

The unvegetated flats give way landward to *Rhizophora* woodland (Fig. 8). This woodland is well watered and is composed of dense red mangrove at least 4 m high. It apparently escaped the hurricane damage that appears to have destroyed the vegetation on the east edge of the island. Rapid accumulation of low ash peat is characteristic of this environment.

***Rhizophora* Scrub**

There is a slight increase in topographic relief in the central part of the island west of the *Rhizophora* woodland. In this area, classified as *Rhizophora* scrub, red mangrove about 2 m in height is dominant. The trees are twisted and probably old. The lower limbs are covered with yellow lichens and a thick litter of leaves lies on the ground. These trees appear to be suffering from nutrient deficiency, a typical phenomenon of both temperate and tropical wetlands having raised surfaces (Cameron et al., 1989). At this location on Tobacco Range, trees are almost beyond the reach of tidal nutrients. The peat that has accumulated under this *Rhizophora* scrub community is undergoing decomposition faster than it is accumulating. If a depression forms from continuing decomposition, another pond may occupy the area, or perhaps the neighboring waterway will shift to this location and begin a new cycle of accumulation.

The flourishing young red mangroves in shallow waters or rooted in the mud in nearby open water ponds and lagoons contrast sharply with the older mangroves. At the present time, these are shrubs that represent the beginning of another mangrove growth cycle. The mud that these young trees are rooted in rests on peat having lower ash content. The stems and leaves of these young mangroves fall on the saturated substrate and rapidly accumulate to form a low ash peat.

Rhizophora Thicket

The *Rhizophora* thicket lies at a slightly lower elevation than *Rhizophora* scrub. The red mangroves of this community are taller, about 2 to 4 m in height. Peat having an ash content more than 31 percent could be expected if the prop roots continue to maintain their position above the optimum tidal nutrient supply.

Western Part of the Island

Continuing westward along the traverse is another area of *Rhizophora* scrub with old trees on high peat surfaces and young trees in and around the margin of ponds forming thickets. The *Rhizophora* scrub then grades into an *Avicennia* woodland dominated by black mangrove. Stands of black mangrove dominate this leeward side of the island and the tip of the windward northeast coast (Woodroffe, 1995, this volume). *Avicennia* open woodland fosters relatively rapid production of low ash peat.

Physical Description of the Peat of Tobacco Range

Cores taken through these different environments all consist of peat having visible amounts of ash that generally overlies peaty mud and mud. Red and black mangroves, the dominant trees of the north island, are the source of most of the peat which is composed of partly decayed plant structures that are unique to mangrove. In order to survive in an environment of high salinity, storms of hurricane proportion, and anoxic soil chemistry, mangroves have developed structures to control concentration of salts in the tissues: prop roots, pneumatophores, and viviparous seedlings.

Distinguishing features of mangroves include prop roots of red mangroves (*Rhizophora)*, and pneumatophores in black mangrove (*Avicennia*). Pneumatophores stand like pencils, 20 to 30 cm above the ground. Both prop roots and pneumatophores have small pores through which oxygen enters the plant when exposed to the air at low tide. If the tidal range stabilizes above the prop roots and pneumatophores, the mangroves die from lack of oxygen (Macnae, 1963; Day, 1981).

Red mangroves have seeds that germinate while they are still on the parent tree.

These long cigar-shaped viviparous seedlings are an adaptation for seedling success in shallow anaerobic waters and sediments that, otherwise, would prevent seeds from sprouting. The seedlings fall from the branches and root if they fall on sediment or float and drift in ocean currents and tides. The seedlings assume vertical positions and the matrix of interwoven roots that characterize red mangrove peat is initiated.

The peaty muds and muddy peats that rest on a thin layer of gray clay or "basal muds" (Macintyre et al., 1995, this volume) beneath the root matrix often contain *Thalassia* (sea grass) that also forms part of the substrate over limestone. Various amounts of unconsolidated rock fragments and other inorganic sediment may also be included. The overlying peat is largely compact, inelastic, and has structured fine fibers representing the narrow interwoven root fibers derived from *Rhizophora*. Broad, thick fibers tend to be derived from stem, prop roots, and pneumatophores of *Avicennia*, and of course the red mangrove, because the two types occur together. Various amounts of unconsolidated inorganic sediment may be mixed with the root and stem fibers of the peat along with more or less decayed leaves, twigs, and other plants living in the mangrove habitat.

A striking characteristic of the entire deposit above the base is its alternating zones of higher and lower ash content. These higher ash zones are peaty mud and muddy peat, containing remains of microscopic aquatic plants that were alive on the floors of ponds and lagoons and include the remains of molluscs and other aquatic invertebrates.

The mud and peaty muds that occur above the bases of the cores appear similar to the mud flats and shallow water bodies on the island crossed by the core traverse (Fig. 2). They may represent ancient mud flats and pond bottoms similar to those at the surface today. This high ash material is much less permeable than the overlying fibrous peat. The decreased permeability of this underlying dense material produces a slippery contact. It is possible that under the stress of severe storms, the slippery contact encourages breaks. However the patterns of fractures at right angles to the shoreline and the oozing of dark humic waters at depth (see Littler et al., 1995, this volume) indicate that subsurface hydostatic flows may be leading to the decomposition and subsequent collapse of the fine fibered peat.

The peat formed from red mangrove tends to have a reddish color derived from the pink hue of the root cortex; peat from other sources appears grayer or browner. Highly decomposed peat appears fine grained and very dark in color.

Table 1 shows data for moisture, ash, percent volatile matter, percent fixed carbon, BTU, and percent sulfur determined by proximate analysis of two samples collected from cores on land (TR1 and F) and one core from below sea level (TR5), corresponding data for major elements, ash, and moisture determined by ultimate analyses, and corresponding data on forms of sulfur. All have similar ash contents (Table 1) and BTU values are not strikingly different, but the sample from the interior of the island appears to have a higher sulfur content than those from the margin and offshore. Decay of vegetation in a pond probably is the explanation for the higher sulfur values. Average acidity for the cores is mostly between pH 4.9 and 6.7, which is typical of a reef environment.

Ash Content of the Peat

Peat samples taken from the cores were analyzed for their organic and inorganic contents (Tables 2 and 3). The data are arranged in order of the cores along the northwest-northeast traverse (Fig. 3) beginning with Vibracore TR5 at the northeast end. A relationship that appears among texture, permeability, and ash content is that a decrease in ash content together with increased porosity results in greater permeability.

Ranges in ash content in the cores of Tobacco Range are shown in Figures 4, 5, 6, and 7. Nondecomposed fibers were examined. Fiber shapes and sizes were largely related to the type of source vegetation in the mangrove communities. Fine fibers are largely associated with root networks of young red mangroves and all partly decomposed older peats; coarse fibers are associated with prop roots of red and black mangrove as well as the leaves and stems of the associated herbaceous plants. Oxidation results in dark-colored, weathered-looking friable fibers and reduces the thinner herbaceous material to a dense fine fibered mass. Decomposed material has higher ash content than the fresher material.

Ash content in these typical peat deposits is a complex issue. Ash consists of volcanic ash blown in from the mainland, sedimentary minerals from pond deposits, minerals precipitated from sea water, and minerals taken up by the plants. The average ash content of the peat in the interior sites of accumulation on the island is therefore higher than in cores at the edges of the island.

Vibracores TR2, TR1, and TR3 have average ash contents of 21.1, 26.6, and 18.5 percent in contrast to inland cores J, I, F, D, and B, that have average ash contents of mainly plant origin of 51.5, 30.0, 34.7, 31.3, and 36 percent, respectively. The increase of ash is attributed to the dominance of periods of slower growth and weathering at these sites. Offshore Vibracore TR5 has an ash content of 37.6%. This site is now more than 4 m below sea level (BSL), but prior to 5,000 yrs B.P. when peat accumulation occurred, the mangroves that deposited the peat may have not been at the edge of the shore. At the edge, they would have been easily reached by tidal currents enriched with nutrients.

Descriptions and details of individual cores

Vibracore TR5 (Fig. 4) is 5.8 m long taken at a depth of 4.2 m below MSL. Bedrock was not reached by the vibracore. The core represents the peat stratigraphy accumulated between about 7,000 and 5,000 yrs B.P., when the peat island was being built as the sea receded. Overlying the basal muddy peat is reddish-brown fine-fibered peat derived from young mangroves. This peat is overlain by one derived from a mature mangrove forest that provided a large wood and leaf matrix. The uppermost intervals sampled contain peat reworked by waves together with *Thalassia* fragments, sand pockets, and mollusc shells, all of which were a part of the sea floor.

Vibracore TR4 from 5.8 meters below MSL represents peat talus 2.8 m thick that slumped from land transgressed by the sea more than 5,500 yrs. BP. The upper part of the core is reworked broad-fibered peat and sand that later formed a bed for the growth of *Thalassia* below the sea surface.

Vibracore TR6, a 2.7 m long remnant between 5,700 and 7,000 yrs B.P. lies close to bedrock. It consists of sandy mud and muddy peat overlain by low ash, fine-fibered peat. Above this is decomposed fine-fibered peat that, in turn is overlain by a relatively fresh broad-fibered, low ash peat derived from both red and black mangrove. The uppermost sample is a dark brown and gray organic-rich watery mud.

Vibracore TR2 (Fig. 4), located just offshore 0.7 meters under the ocean surface, is 7.5 meters long and rests on limestone. The upper part of the core was reworked in the course of the sea's transgression and is sandy mud with sand pockets and sea shells. The upper middle tends to be broad-fibered peat whereas the bottom middle is more fine-fibered (Macintyre et al., 1995 this volume). The striking feature of this core is its predominance of fresh or lower ash permeable peat alternating with higher ash peat that indicate alternating periods of faster and slower growing red mangrove communities. The ash contents are between 10.7 and 28.8 percent except one sample (No. 25, Fig 4) in which it is as high as 31 percent.

Vibracore TR1 (Fig. 5) at the island's edge is also characterized by low ash peat. Like core TR2, it is favorably located for tidal nutrient supply to the mangroves and like TR2 the top of the core is dominated by broad-fibered peat whereas the bottom of the core consists mainly of fine-fibered peat (Macintyre et al., 1995 this volume). The ash content ranges between 15 and 30 percent through much of the core. Ash content is higher at the base, where the peat rests on clay over bedrock, but above the base ash content between 31 and 38 percent is reached at the top (samples No. 1 and No. 2), just above and below the 2-m depth mark (samples No. 7 and No. 8), at the 5-m depth (sample No. 13), and below the 6-m depth (sample No. 16). Thus, the alternation of fast- and slow-growing mangroves is sharply evident.

Probe holes A, K, and G were probed primarily to obtain depth to bedrock. These data are shown in Figure 3 and Tables 2 and 3. Probe hole J (Fig. 5) is located in the interior of the island where the mangroves receive nutrients from tidal waterways. Samples from probe hole J indicate that red mangroves were established on a totally exposed sea bottom about 5000 yrs BP in the organic material on the basal clay lying over Pleistocene limestone. They continued to thrive with a mixture of black mangrove while another meter of peat accumulated; the peat then weathered until the surface formed a depression holding a pond or tidal waterway, where the muddy peat (sample No. 47) accumulated (Fig. 5; Table 3). Young mangroves rooted and thrived, as interpreted from very fresh low ash peat (sample No. 46). During the past 3,500 years, the surface has been building until today it is high enough to be covered by low standing red mangroves.

Probe hole I (Fig. 6) almost 8 m deep, has a base of high ash peat interpreted as the deposit of red mangrove that took root on the sea bottom. Above this base peat was formed from the plants that grew as sea level rose, reaching a peak of rapid growth as indicated by a sample at a little over 6 m deep (sample No. 43) and then slowed indicated by samples in the next 2 meters, when black mangroves became more numerous. They were followed by a surface depression as recorded in a sample a little less than 3 meters in depth (sample No. 40), then peat in this core was formed from plants with an increased growth rate reaching a maximum rate at less than 2 meters in depth (sample No. 39). Finally, the rate of plant growth slackened until presently the still-living red mangroves are old and stunted. This surface will most likely subside as decomposition of the peat substrate overtakes accumulation.

Probe hole F (Fig. 6) extends from about 0.2 m ASL to bedrock at a depth of 10.19 below MSL and represents the thickest peat section sampled in this study. After red mangrove was established on the muddy sea floor over Pleistocene limestone, growth remained remarkably uniform while 5 m of peat with an ash content of about 32 to 41 percent slowly accumulated in a swamp lying in the interior of the island. A pond then developed on the surface, which promoted more rapid growth of mangrove and accumulation of peat with lower ash content in water having much higher sulfur content (7.4 percent) than the muddy peat above or below where sulfur ranges between 3.8 and 4.3 percent. After the pond filled and the peat surface rose higher, mangrove growth slowed and the peat weathered somewhat until an elevation of 2.2 m (sample No. 29) was reached. Since then, mangroves have grown rapidly in and above a waterway with good tidal circulation until the surface today is almost out of reach of tidal influence, and the ash content is 26.3 percent.

Probe hole E is located on the unvegetated flats that were probably swept by a hurricane to expose the underlying substrate, which is a comparatively low ash red and black mangrove peat. The base of the core is similar to the other cores and is resting on Pleistocene limestone. Muddy peat and peat alternating through the core suggests rapid and slow mangrove growth corresponding to the rising and subsiding surfaces resulting from rapid and slow peat accumulation, which is caused by decomposition, or removal of vegetation by hurricanes, while sea level continued to rise.

Probe hole D (Fig. 7), also located on the unvegetated flats, has a history similar to Probe hole E. Red mangroves established themselves on the muddy sea floor of a limestone trough; peat accumulation was rapid at first (sample No.24) became slower until sea level rose over the site (sample No. 23), which led to rapid plant growth again (sample No. 22). The characteristics of the peat in the remaining 5.7 m of the 8.6-m core indicates growth was remarkably uniform, progressing at a moderately slow rate in a mixed red and black mangrove swamp until the hurricane swept the surface. Today the vegetation is once again becoming established.

In Probe hole D the core pH is above 6 at all levels and reaches 7.2 in the muddy peat (samples No.19, 20 and 21) that appear to be formed largely from a mixture of black and red mangrove prop roots together with the herbaceous vegetation, vines, and shrubs that are characteristic of the island interior. The greatest concentration of ash is in the muddy peat in the upper part of the deposit in cores 18 and 19, which have ash contents of 31.2 and 32.4 percent respectively. The low concentration of ash in the base of this core could be explained if ground waters moved down the limestone slope and dissolved the minerals in the ash and removed them from the system.

Probe hole B (Fig. 7), located on higher ground near the leeward shore in the *Avicennia* open woodland with *Rhizophora* vegetation type, extends from about 0.1 m above MSL to limestone in the bottom of the trough 9.53 m below MSL. The history recorded in the peat is typical of the development of the island's interior, namely an alternation of slightly faster and slightly slower rates of growth of an initial predominantly red mangrove forest followed by a mixed red and black mangrove forest and overlain by the deposits formed by washover of the shore by high seas.

Vibracore TR3 (Fig. 7) is located under shallow water at the edge of the island where tidal currents facilitated mangrove growth and accumulation of peat. Today the core is 0.2 m below MSL, and extends to a limestone ridge or platform about 6.5 m below MSL. The top of the core consists of a reworked peat surface that is the result of marine erosion.

It now lies under the sandy sea floor and *Thalassia* growth.

Probe hole C samples No.15, 16, and 17 are muddy peat having ash contents of 45.8, 49.8, and 35.4 percent respectively. The upper two samples, mixed with sand and shells, lie at a depth of 1.5 meters BSL. Like Probe hole D, this core is alkaline with a pH of 7.6 for the upper two samples and 7.7 for the lowest sample.

Trace Element Distribution

The trace element contents determined in the cores are highly differentiated and may help interpret differing concentration mechanisms. As shown by Figures 4, 5, 6, and 7, trace elements are distributed heterogeneously. Many elements vary by more than an order of magnitude within each core (see Table 3). There are also large variations in the average concentrations of most elements between cores.

The behavior of trace elements in the peat are greatly affected by their concentration in sea water. This is not surprising because the island is surrounded by sea water, and mangroves, which constitute the major source of the peat, grow in sea water. Elements can be classified into three groups based on their concentration in sea water. The first group, S, Ba, Na, Br, Rb, and Sr, which forms the most homogeneous group of all the elements, all have concentrations of greater than 0.01 ppm in sea water (Taylor and McLennan, 1985) that is uncontaminated by fresh water. The concentrations of this group of elements are similar from core to core and from one part of a single core to another part. Compared to the other elements, the range of concentrations in the dried peat is small. It is only 1 to 2 orders of magnitude compared to up to nine orders of magnitude for elements in other groups. Na, Rb, and Br are clearly associated with NaCl and are highly statistically correlated. Ba and Rb as well as S and Sr are also highly correlated in these samples, but many of the element pairs are not correlated. This is probably due to differing mechanisms of absorption from sea water that, together with small differences in overall concentration ranges, reduces the chance of correlations.

A second group of elements that have concentrations of less than 0.1 ppb in sea water show large differences in concentrations between samples of the same and other cores. These elements (Hg, Fe, Co, Hf, Ta, Th, W, Sc, La, Ce, Nd, Sm, Eu, Tb, Yb, Lu, and Au) are generally associated with the inorganic minerals (ash) found in peat. Except for Au and Hg, which are not correlated with any other elements, these elements are highly correlated with each other.

Elements with concentrations between 0.01 ppm and 0.1 ppb, such as As, Cr, Cs, Sb, Se, U, and Zn, belong to the third group in which differences in concentrations from place to place are not as pronounced as those of the second group but are more pronounced than those of the first group. Except for Se, these elements are highly correlated with each other.

U is also highly associated with Ba in group one. Data suggest that both elements are associated with both organic and inorganic portions of the peat to the same extent. The association is likely due to the size of these large lithophilic elements because the ions have different charges. Ba and Sr with similar charges do not correlate as well as Ba and U.

Correlation matrix analysis of individual cores was carried out to determine if each core followed the trends of the whole data set. In Vibracore TR1, As is more closely correlated with Ba and U than in other cores. Sr, is highly correlated with Na and Br in Vibracore TR2. Sb, As, and Se appear to be associated with the sulfide fraction. Interestingly, Cr is also associated with these sulfide elements and more weakly associated with the lithophilic elements in this core. Correlations of these elements in other cores are generally similar to correlations determined on the whole data set.

The concentrations of elements in the Tobacco Range peat are strikingly similar to those in the Indonesian fresh water peats along the Batang Hari River in Sumatra (Cameron et al., 1989). Of course, the elements of the first group, namely 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 they were largely added to the peat after the plants died and did not have a significant role in tissue building. Most of the average concentrations of the other elements are similar to the Indonesian peats within a factor of two. This may mean that the Tobacco Range peat like the Sumatra peat has a terrestrial source of elements brought to each deposit from volcanic dust and pumice which even today wash up on the shores periodically in large amounts.

These offshore islands, which are on limestone bedrock, now have no clear terrestrial source other than the volcanic dust and pumice mentioned above. Although there is no evidence that the limestone supporting the peat of Tobacco Range may have supplied the mangroves with groundwater from the continent via systems of increased porosity, we speculate that such a source could exist especially along the north-northeast-trending faults dipping to the southeast with recharge areas in the mountainous uplands of northern Belize and Yucatan (Miller and Macintyre, 1977). A recharge area may also lie in the flat low-lying northern part of the Yucatan Peninsula; Hanshaw and Back (1980) discussed that the Yucatan lacks stream channels even though there is a mean annual discharge of 8.6 million m^3 for each 1 km of the 1,100-km coastline. However, the editors of this volume (1995, personal communication) do not believe that groundwaters are present at Tobacco Range and state that waters in a cave 100 m below MSL off Columbus Cay to the north show no signs of groundwater, with salinities of normal seawater levels.

The presence of fresh ground water in the limestone of Tobacco Range from the continent would support the explanation of a terrestrial source of elements as the plant nutritive source and could be a partial explanation for the slumping of peat off the edge of the island. However, extensive measurements by the Littlers' research group throughout the Tobacco Range fracture zone over a three year period, including the deeper humic water seeps, showed no dilution by freshwater sources (M.and D. Littler, 1995, personal communication).

SUMMARY

Tobacco Range is an island of mangrove peat built on a limestone platform that was topographically high during the Late Pleistocene when the ocean regressed to the east beyond the present coral reef crest.

Exclusive mangrove peat accumulation kept up with sea level rise but not at an even pace. Mangroves grew faster when they were within the optimum range of nutrients governed by tidal range. Different plant communities took hold: *Avicennia* Open

Woodland with *Rhizophora*, unvegetated flats, *Rhizophora* woodland, *Rhizophora* scrub, and *Rhizophora* thicket. Such processes account for the heterogeneity of ash and trace element contents in the peat.

The geologic history also affects the composition of the peat. Volcanic eruptions on the mainland have significantly affected the nutrients available for plant growth, the ash content and the trace element distribution in the peat. There are similarities in elemental composition with the fresh water Sumatra peats which have a history of volcanic eruptions and these mangrove (salt water) peats, which suggests that volcanic ash and incorporation into biomass may be an important factor in the trace element distribution. Although there is no supporting evidence, it is also possible that the tilted fault blocks of the continent and the shelf could provide conduits for dissolved elements from the continental rocks that may still continue to reach the peat and mangroves as groundwater discharges in the Tobacco Range.

REFERENCES

Adey, W.H., Macintyre, I.G., and Stuckenrath, R. 1977. Relict barrier reef system of St. Croix, its implications with respect to late Cenozoic coral reef development in the western Atlantic: International Coral Reef Symposium 3rd, Miami Beach 1977: University of Miami v. 2, p. 15-21.

American Society for Testing and Materials, 1969, Standard classification of peats, mosses, humus, and related products: Philadelphia, Pennsylvania, American Society for Testing Materials, Do-69, 1 p.

Cameron, C.C. 1972. Diagenesis and quality of peat deposits, Proceedings of the Fourth International Peat Congress, Otaniemi, Finland, 1972, v. 1, p. 233-245.

________, 1988, Comparison of two tropical and north temperate peatlands in Sumatra and Maine: Proceedings of the Symposium '87 Wetlands and Peatland:Wetland/Peatland, Edmonton, Canada, p. 355-361.

Cameron, C.C., Esterle, J.S., and Palmer, C.A. 1989. The geology, botany and chemistry of selected peat-forming environments from temperate and tropical latitudes: International Journal of Coal Geology, v. 12, p. 165-156.

Chapman, V.J. 1976. Mangrove vegetation: Vaduz, Germany, J. Cramer Publications, p. 1-447.

Day, J.H. 1981. Estuarine ecology: with particular reference to southern Africa, Rotterdam, A.A. Balkema, 411 p.

Hanshaw, B.B., and Back, W. 1980. Chemical mass-wasting of the northern Yucatan Peninsula by groundwater dissolution, Geology, v. 8, no. 5, p. 222-224.

Kivinen, E., and Pakarenen, P. 1980. Peatland areas and the proportion of virgin peatlands in different countries, Proceedings of the International Peat Society., 6th International Peat Congress, Duluth, Minn., p. 52-54.

Kjerfve, B., Ruetzler, K., and Kierspe, G.H. 1982. Tides at Carrie Bow Cay, Belize, In Ruetzler, K. and Macintyre, I.G. eds. The Atlantic barrier reef ecosystem at Carrie Bow Cay, Belize; Part 1 Structure and communities: Smithsonian Institution, Contributions to the Marine Sciences, v. 12, p. 47-61.

Littler, M.M., Littler, D.S., Macintyre, I.G., Brooks, B.L., Taylor, P.R., and Lapointe, B.E. 1995. The Tobacco Range Fracture Zone, Belize, Central America: A unique system of slumped mangrove peat. Atoll Res. Bull., No. 428, p.1-31.

Lightly, R.G., Macintyre, I.G., and Stuckenrath, R. 1983. Holocene sea-level curve for the Caribbean and tropical Atlantic based on coral growth of shallow-water Acropora palmata reef framework: American Geophysical Union, v. 64, no. 52, p. 1886.

Macintyre, I.G., Littler, M.M. and Littler, D.S. 1995. Holocene history of Tobacco Range, Belize, Central America. Atoll Res. Bull., No. 430, p. 1-18.

Macnae, W. 1963. Mangrove swamps in South Africa, Journal of Ecology, 51: 1-25.

Miller, J.A., and Macintyre, I.G. 1977. Field guidebook to the reefs of Belize, Third International Symposium on Coral Reefs, University of Miami, Fisher Island, Miami Beach, Florida: University of Miami, p. 1-36.

Mitsch, W.J., and Gosselink, J.G. 1986. Wetlands: New York, Van Nostrand Reinhold, p. 1-515.

Ruetzler, K., and Macintyre, I.G. 1982. The habitat distribution and community structure of the barrier reef complex at Carrie Bow Cay, Belize. In Ruetzler, K. and Macintyre, I.G. eds. The Atlantic barrier reef ecosystem at Carrier Bow Cay, Belize 1: Structure and communities, Smithsonian Institution Contributions to the Marine Sciences v. 12 p. 9-45.

Shinn, E. A., Hudson, H., Haley, R.B., Lidz, B., Robbin, D., and Macintyre, I.G. 1982. Geology and sediment accumulation rates at Carrie Bow Cay, Belize, In K. Rutlzer and Macintyre, I.G. eds. The Atlantic Barrier Reef Ecosystems at Carrie Bow Cay, Belize, Part 1. Structure and communities, Smithsonian Contributions to the Marine Sciences No. 12, Washington, DC, p. 67-75.

Taylor, S.R., and McLennan, S.M. 1985. The continental crust: Its composition and evolution: Blackwell Scientific Publications, 312 p.

Woodroffe, C.D. 1983. The development of mangroves from a geological perspective. In H.J. Teas, ed. Biology and Ecology of mangroves: Dr. W. Junk, The Hague, p. 1-17.

Woodroffe, C.D. 1995. Mangrove vegetation of Tobacco Range and nearby mangrove ranges. Atoll Res. Bull., No. 427, p. 1-29.

Table 1. Proximate and ultimate analyses and sulfur forms of three samples of Tobacco Range peat (Dickerson Labs, Inc.)

Proximate Analysis	As Received	Dry Basis	Moisture & Ash Free Basis	Ultimate Analysis	As Received %	Dry Basis %	Sulfur Forms	As Received %	Dry Basis %
(a) Sample 5 at depth of about 1.3 meters at core site TR1									
% Moisture	30.78			Moisture	30.78		Pyritic	0.00	0.01
% Ash	21.79	31.78		Carbon	25.55	36.92	Sulfate	0.68	0.99
% Volatile	33.04	47.73	69.65	Hydrogen	2.52	3.64	Organic	2.07	2.97
% Fixed Carbon	14.39	20.79	30.35	Nitrogen	0.71	1.02	Total	2.75	3.97
				Chlorine	9.28	13.40			
				Sulfur	2.75	3.97			
Btu	4553	6578	9600	Ash	21.79	31.48			
				Oxygen (diff)	6.62	9.57			
% Sulfur	2.75	3.97							
(b) Sample 47 at depth of about 6 meters at core site TR5									
% Moisture	45.43			Moisture	45.43		Pyritic	0.00	0.01
% Ash	17.08	31.30		Carbon	21.43	39.27	Sulfate	0.41	0.76
% Volatile	26.84	49.20	71.61	Hydrogen	1.97	3.62	Organic	2.08	3.80
% Fixed Carbon	10.65	19.5	28.39	Nitrogen	0.35	0.65	Total	2.49	4.57
				Chlorine	6.67	12.22			
				Sulfur	2.49	4.57			
Btu	3734	6842	9960	Ash	17.08	31.3			
				Oxygen (diff)	4.58	8.37			
% Sulfur	2.49	4.57							
(c) Sample 31 at depth of about 5 meters at core site F									
% Moisture	89.13			Moisture			Pyritic	0.00	0.01
% Ash	3.33	30.60		Carbon	4.25	39.1	Sulfate	0.07	0.66
% Volatile	4.66	42.91	61.83	Hydrogen	10.39	3.79	Organic	0.49	4.46
% Fixed Carbon	2.88	26.49	38.17	Nitrogen	0.08	0.71	Total	0.56	5.13
				Chlorine					
				Sulfur	0.56	5.13			
Btu	756	6954	10020	Ash	3.33	30.60			
				Oxygen (diff)	81.39	20.67			
% Sulfur	0.56	5.13	7.40						

Table 2. Qualitative data for peat core samples located on cross section (fig. 3) listed from northwest to southeast along traverse line.

Core	Sample Number	Total Sulfur (%)	Ash (dry) (%)	pH	Lithology	Comments
TR5..............	72				muddy peat	Dark brown coarse fibers, sand pockets; mollusk shells, Thalassia.
	46	3.6	38.9	6.3	muddy peat	Red brown coarse fibers; reworked by the sea as in Sample 72.
	47	4.6	31.3		muddy peat	Dark brown coarse fibers.
	48	3.7	37.1	5.2	muddy peat	Dark brown coarse fibers.
	49	4.2	51.8	6.9	muddy peat	Dark brown fine fibers.
	50	4.3	32.1	5.9	muddy peat	Dark red brown, large wood fragments; mature.
	51	5	35.2	4.9	muddy peat	Dark red brown, large wood fragments; mature; with leaves.
	52	4.7	30.6	4.9	peat	Red brown fine fibers peat.
TR4.............	74				muddy peat	Dark brown coarse fiber peat, sand, Thalassia fragments.
	75				muddy peat	Dark brown coarse fiber peat and sand.
	76				muddy peat	Brown fine fibered peat.
	77				muddy peat over peaty mud	Dark brown organics over grey dense mud over watery mud, wood, and sand.
TR6.............	78				muddy peat	Dark brown gray; organic; water.
	44	4.6	24.6	5	peat	Medium brown, coarse fibered.
	80				peat	Brown; fine fibers.
	45	4.1	28.8	4.8	peat	Brown; fine fibers.
	81				muddy peat	Sandy.
TR2.............	82				peaty mud	Gray brown mud with sand fragments and shells. Reworked.
	22	4.3	28.8	4.9	peat	Fine fibered red brown; many mollusk shells. Reworked by sea.
	23	4.4	14.1	4.7	peat	Coarse fibers; red brown; prop roots; leaves. Mostly red mangrove.
	24	4.1	13	4.5	peat	Coarse fibers; red brown; prop roots; leaves. Mostly red mangrove.
	25	4.6	31	4.9	peat	Coarse fibers; red brown; prop roots; leaves. Mostly red mangrove.
	26	4.5	23.1	4.7	peat	Dark red brown fine fibers. Root mat.
	27	5.5	16.5	5.5	peat	Dark red brown fine fibers. Root mat.
	28	3.6	27.6	5.9	peat	Dark red brown fine fibers. Root mat.
	29	5.6	14.6	5.5	peat	Dark red brown fine fibers. Root mat.
	30	5.1	10.7	4.4	peat	Dark red brown fine fibers. Root mat.
	31	5.2	14.3	5.4	peat	Dark red brown fine fibers. Root mat.
	32	4.7	24.2	5.2	peat	Dark red brown fine fibers. Root mat.
	33	5.2	28.3	4.3	peat	Dark red brown fine G18fibers. Root mat.

Table 3. Elements in samples taken from cores along northwest-southeast traverse (fig. 2) listed by sample number (fig. 3). Averages for each element in each core are given. In cases where less than two data points are available for a given element in a given core the average could not be calculated and is indicated by ---.

Core	Sample No.	S (%)	Hg (ppm)	Ash (%)	pH	Fe (%)	Na (%)	As (ppm)	Ba (ppm)	Br (ppm)	Co (ppm)	Cr (ppm)
TR5	46	3.60	< 0.005	38.9	6.3	0.036	4.9	7.6	268	920	0.255	2.28
	48	3.70	< 0.005	37.1	5.2	0.947	3.6	28.4	495	711	2.58	33.2
	49	4.20	< 0.005	51.8	6.9	0.150	6.5	< 5	297	1210	0.82	8.1
	50	4.30	< 0.005	32.1	5.9	0.019	4.2	5.80	245	860	0.509	2.66
	51	5.00	< 0.005	35.2	4.9	0.552	5.2	8.7	461	1030	1.67	8.8
	52	4.70	< 0.005	30.6	4.4	0.735	3.6	7.0	457	648	11.5	14.6
	AVG TR5	4.25	---	37.6	5.6	0.406	4.67	11.4	372	890	2.89	11.6
TR6	44	4.60	< 0.005	24.6	5.0	0.089	4.8	7.9	317	1260	5.05	5.4
	45	4.10	< 0.005	28.8	4.8	0.276	4.8	< 5.0	150	810	1.06	6.4
	AVG TR6	4.35	---	26.7	4.9	0.183	4.8	---	235	1055	3.08	5.90
TR2	22	4.30	< 0.005	28.8	4.9	0.153	7.5	19.3	258	1140	0.49	12.8
	23	4.40	< 0.005	14.1	4.7	0.138	5.9	16.1	486	861	0.47	12.8
	24	4.10	< 0.005	13.0	4.5	0.039	6.1	8.7	540	815	0.261	7.2
	25	4.60	< 0.005	30.2	4.9	0.081	7.4	< 4	558	1120	0.505	12.1
	26	4.50	< 0.005	23.1	4.7	0.222	7.1	7.2	480	959	0.62	19.6
	27	5.50	< 0.005	16.5	5.5	0.042	5.6	< 6	167	668	0.173	1.51
	28	3.60	< 0.005	27.6	5.9	0.037	12.1	< 6	274	1630	0.441	1.76
	29	5.60	< 0.005	14.6	5.5	0.419	7.4	< 4	346	926	0.80	11.5
	30	5.10	< 0.005	10.7	4.4	0.211	7.7	< 7	524	1000	0.87	4.79
	31	5.20	< 0.005	14.3	5.4	0.045	7.8	< 4	488	976	0.41	2.2
	32	4.70	< 0.005	24.2	5.2	0.100	10.5	6.9	81	1100	0.54	2.52
	33	5.20	< 0.005	28.3	4.3	0.107	7.8	5.4	113	964	0.50	1.85
	34	5.10	< 0.005	15.4	5.4	0.198	5.09	< 3	63	587	1.14	2.35
	AVG TR2	4.76	---	20.1	5.0	0.138	7.57	10.5	337	980	0.552	7.25
TR1	1	2.20	0.01	37.6	6.3	0.048	7.1	< 12	241	2140	0.200	6.40
	2	3.50	< 0.005	32.8	5.7	0.129	4.51	25.8	705	1270	0.722	10.7
	3	4.20	< 0.005	23.8	5.4	0.095	4.2	15.5	267	990	0.338	9.00
	4	4.20	< 0.005	27.2	5.6	0.031	4.8	< 5	386	1080	0.197	4.03
	6	1.40	< 0.005	27.7	4.9	0.067	4.2	< 8	730	980	0.282	8.9
	7	4.40	< 0.005	34.3	4.8	0.151	5.2	< 8	320	1190	0.359	11.9
	8	3.90	< 0.005	33.8	5.3	0.132	6.3	< 9	382	1470	0.379	11.3
	9	4.30	< 0.005	18.6	4.8	0.166	4.7	< 8	< 60	1140	0.531	19.1
	10	4.50	< 0.005	20.2	5.2	0.162	4.8	< 7	221	1030	0.410	18.1
	11	4.10	< 0.005	16.7	4.9	0.160	4.4	9.5	< 70	930	0.418	19.1
	12	4.60	< 0.005	19.7	5.1	0.204	3.7	< 7	477	810	0.46	20.4
	13	3.80	< 0.005	37.7	4.7	0.019	8.2	< 10	169	1530	0.144	2.91
	14	5.30	< 0.005	17.3	5.2	0.300	3.5	< 7	311	695	0.78	10.7
	15	5.00	< 0.005	22.0	5.1	0.170	3.4	< 8	463	860	0.727	5.94
	16	5.40	< 0.005	31.1	5.4	0.043	9.85	16.0	360	1100	0.73	3.33
	17	4.20	< 0.005	28.7	4.9	0.050	12.0	< 4	201	896	0.32	1.90
	18	2.40	< 0.005	17.4	5.9	0.269	6.2	6.5	58	625	1.43	5.71
	19	5.60	< 0.005	14.6	4.6	0.200	6.5	< 3	36	628	1.08	2.78
	20	5.30	< 0.005	26.7	4.4	0.896	7.1	< 3	50	687	2.45	13.3
	21	4.30	< 0.005	44.1	3.3	1.93	3.53	7.3	91	331	4.45	52.9
	AVG TR1	4.13	---	26.6	5.1	0.261	5.71	13.4	304	1017	0.822	11.9
A	4	4.20	0.010	48.1	3.90	1.60	6.54	9.5	130	617	5.13	43.4
J	47	3.80	< 0.005	69.5	5.60	3.41	3.25	23.1	190	334	11.1	95
	48	4.60	< 0.005	30.1	5.90	0.065	6.2	4.9	113	< 500	0.304	2.30
	49	5.10	0.010	33.0	5.30	0.157	5.4	4.4	324	< 500	0.66	5.99
	50	4.10	< 0.005	30.4	5.90	0.076	6.4	5.7	83	< 500	0.455	2.68
	51B	4.50	0.010	87.4	3.40	5.13	1.15	17.2	110	76.0	13.4	130
	AVG J	4.42	0.010	50.1	5.22	1.77	4.50	11.0	163	203	5.18	47

Table 3 (continued)

Core	Sample No.	Cs (ppm)	Hf (ppm)	Rb (ppm)	Sb (ppm)	Se (ppm)	Sr (ppm)	Ta (ppm)	Th (ppm)	U (ppm)	W (ppm)	Zn (ppm)
TR5	46	0.029	< 0.04	1.33	0.44	0.86	165	0.025	0.0800	42	---	3.01
	48	2.12	0.97	29.4	1.60	2.77	318	0.312	2.50	63	---	15.5
	49	0.295	0.145	4.5	0.37	1.01	248	0.044	0.420	45	---	3.6
	50	0.048	0.044	1.14	0.19	1.11	90	0.017	0.110	38	---	2.14
	51	0.333	0.229	4.9	0.383	1.26	107	0.053	0.560	70	---	6.1
	52	0.64	0.466	8.0	0.60	1.24	108	0.114	1.30	66	---	13.4
	AVG TR5	0.573	0.371	8.13	0.597	1.38	175	0.093	0.828	54	---	7.13
TR6	44	0.281	0.16	4.4	0.329	1.45	116	0.048	0.370	49	---	5.9
	45	0.355	0.23	4.1	0.34	0.63	122	0.058	0.630	20.4	---	6.2
	AVG TR6	0.320	0.195	4.25	0.335	1.06	119	0.053	0.500	34.5	---	6.1
TR2	22	0.241	0.181	3.9	0.61	2.80	154	0.065	0.409	42	---	6.4
	23	0.172	0.130	3.0	0.67	3.25	113	0.032	0.32	76	---	5.7
	24	0.060	0.068	2.1	0.450	2.02	96	< 0.02	0.118	88	---	3.5
	25	0.170	0.107	3.5	0.58	3.04	168	0.035	0.241	92	---	5.0
	26	0.35	0.196	4.7	0.414	3.91	134	0.057	0.53	79	---	5.8
	27	< 0.01	0.095	< 1	0.185	1.08	141	< 0.02	0.041	28	---	2.15
	28	0.043	0.206	2.12	0.280	0.50	182	< 0.02	0.077	49	---	2.8
	29	0.602	0.323	10.2	0.55	1.56	128	0.100	0.90	56	---	9.8
	30	0.206	0.103	4.0	0.353	1.34	122	0.029	0.304	86	---	4.5
	31	0.026	0.025	< 2	0.22	1.22	133	< 0.02	0.087	80	---	3.0
	32	0.112	0.145	2.2	0.380	0.66	174	0.030	0.181	12.9	---	3.3
	33	0.070	0.062	1.5	0.272	0.78	166	0.017	0.164	17.3	---	2.00
	34	0.064	0.075	2.1	0.46	0.74	129	< 0.02	0.23	10.7	---	4.9
	AVG TR2	0.176	0.133	3.6	0.416	1.76	140	0.0456	0.277	55.2	---	4.53
TR1	1	0.149	0.106	3.15	0.85	1.09	167	0.040	0.278	35.9	---	5.9
	2	0.242	0.159	4.2	1.02	2.12	130	0.060	0.400	107	---	12.6
	3	0.157	0.449	3.3	0.319	1.53	102	0.029	0.284	39	---	4.7
	4	0.045	0.027	1.61	0.246	1.07	113	< 0.02	0.097	58	---	3.03
	6	0.093	0.101	1.9	0.396	1.80	96	< 0.02	0.190	111	---	3.9
	7	0.199	0.139	4.3	0.331	2.20	120	0.037	0.328	46	---	5.4
	8	0.167	0.124	3.1	0.268	2.56	114	0.036	0.292	58	---	4.45
	9	0.338	0.179	4.4	0.27	3.28	118	0.061	0.583	47	---	5.2
	10	0.228	0.165	4.3	0.180	3.16	135	0.046	0.47	31	---	5.3
	11	0.191	0.135	4.0	0.180	3.45	129	0.048	0.404	72	---	8.7
	12	0.237	0.174	3.3	0.220	3.53	124	0.040	0.454	72	---	9.5
	13	0.038	0.035	1.87	0.078	0.88	146	< 0.01	0.070	26.3	---	2.3
	14	0.64	0.284	9.0	0.439	1.44	116	0.112	0.783	46	---	5.5
	15	0.248	0.147	4.6	0.279	1.07	139	0.045	0.379	64	---	3.7
	16	0.120	0.092	3.5	0.21	1.02	129	< 0.04	0.189	75	< 4	2.8
	17	0.063	0.071	2.1	0.160	0.67	182	< 0.02	0.138	36	---	2.9
	18	0.363	0.247	3.3	0.34	0.69	149	0.060	0.631	7.8	---	5.5
	19	0.080	0.083	1.7	0.334	0.60	115	< 0.02	0.200	5.4	---	7.8
	20	1.10	0.660	12.0	0.420	0.67	143	0.170	1.58	6.3	---	14.4
	21	4.32	2.87	35.6	0.72	< 2	129	0.701	8.2	7.9	---	39.8
	AVG TR1	0.450	0.314	5.59	0.362	1.73	129	0.106	0.797	47.7	---	7.7
A	4	2.31	1.92	33.2	1.06	< 1	131	0.414	3.53	17.6	---	28.7
J	47	5.83	4.27	68	2.33	1.6	120	0.94	10.1	26.9	---	49.1
	48	0.100	0.078	2.4	0.251	---	115	< 0.03	0.166	19.2	---	2.8
	49	0.245	0.183	4.2	0.49	---	103	0.038	0.320	56	---	2.1
	50	0.089	0.226	1.2	0.187	---	103	< 0.03	0.170	14.5	---	2.1
	51B	9.2	6.7	80	1.26	< 1	95	1.55	18.4	2.61	---	71
	AVG J	3.09	2.30	31.2	0.906	---	107	0.826	5.73	23.7	---	25.4

Table 3 (continued)

Core	Sample No.	Sc (ppm)	La (ppm)	Ce (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Tb (ppm)	Yb (ppm)	Lu (ppm)	Au (ppb)
TR5	46	0.122	---	2.1	---	< 0.2	0.017	0.007	< 0.1	< 0.08	< 25
	48	3.80	3.7	13.7	< 3	0.88	0.240	0.158	0.42	0.122	< 17
	49	0.663	< 2	4.7	---	< 0.3	0.078	0.045	< 0.2	< 0.07	< 30
	50	0.142	---	3.2	---	< 0.2	0.034	0.022	< 0.1	< 0.06	< 18
	51	0.774	---	6.0	---	< 0.4	0.078	0.054	0.34	< 0.1	< 20
	52	1.71	2.5	11.4	< 4	0.76	0.220	0.148	0.65	< 0.1	< 16
	AVG TR5	1.20	3.10	6.8	---	0.82	0.111	0.0730	0.47	---	---
TR6	44	0.548	< 2	6.0	---	< 0.2	0.059	0.042	< 0.2	< 0.08	< 25
	45	0.697	1.4	3.73	< 3	0.32	0.068	0.052	0.20	< 0.02	< 23
	AVG TR6	0.623	---	4.85	---	---	0.0635	0.047	---	---	---
	22	0.771	---	< 6	---	0.29	0.076	0.050	< 0.4	< 0.5	< 25
	23	0.628	---	< 6	---	< 0.2	0.064	0.040	< 0.5	< 0.8	< 19
	24	0.222	---	< 7	---	< 0.2	0.030	0.012	0.18	< 1	< 19
	25	0.416	---	< 5	---	< 0.2	0.037	0.030	< 0.1	< 0.9	< 19
	26	0.90	---	< 7	---	0.3	0.083	0.065	0.44	< 0.8	< 23
	27	0.058	---	< 3	< 2	< 0.1	0.022	0.014	< 0.1	< 0.3	< 14
	28	0.106	---	< 0.9	---	< 0.2	0.012	< 0.005	< 0.2	< 0.5	< 30
	29	1.35	---	< 6	< 3	0.45	0.084	0.063	< 0.2	< 0.5	< 19
	30	0.463	---	< 7	< 4	< 0.2	0.050	0.033	< 0.1	< 0.9	< 25
	31	0.110	---	< 4	< 3	< 0.2	0.026	0.016	< 0.1	< 0.8	< 18
	32	0.197	---	1.21	< 3	< 0.2	0.024	0.014	< 0.2	< 0.2	< 31
	33	0.225	< 0.7	1.5	< 2	0.24	0.028	0.018	< 0.1	< 0.3	< 18
	34	0.278	< 0.7	0.78	< 2	< 0.2	0.036	0.026	0.24	< 0.1	< 17
	AVG TR2	0.444	---	1.16	---	0.31	0.044	0.032	0.29	---	---
TR1	1	0.440	< 0.6	2.56	---	< 0.4	0.050	0.032	< 0.2	< 0.4	< 32
	2	0.651	< 7	6.2	---	< 0.4	0.056	0.040	< 0.2	< 0.2	< 23
	3	0.478	< 1	3.1	---	< 0.2	0.045	0.031	< 0.2	< 0.06	< 20
	4	0.161	---	3.1	---	< 0.3	< 0.03	0.013	< 0.2	< 0.1	< 20
	6	0.344	< 3	5.3	---	< 0.4	0.036	0.021	< 0.1	< 0.2	< 30
	7	0.587	2	3.7	---	< 0.3	0.049	0.035	< 0.2	< 0.04	< 22
	8	0.523	1.7	3.8	---	< 0.3	0.061	0.041	0.33	< 0.08	< 23
	9	0.999	2.8	5.2	---	0.41	0.103	0.070	< 0.5	< 0.08	< 19
	10	0.913	3.1	5.2	< 2	0.39	0.117	0.074	0.37	0.055	< 18
	11	0.838	4.6	6.0	---	< 0.5	0.107	0.081	0.23	< 0.1	< 19
	12	0.936	4.2	6.2	---	0.38	0.121	0.080	0.26	< 0.09	< 16
	13	0.132	2.1	1.59	---	< 0.3	0.027	0.016	< 0.2	< 0.05	< 30
	14	1.23	3.7	5.6	---	0.44	0.083	0.062	< 0.2	< 0.05	< 18
	15	0.619	3.9	6.1	---	< 0.3	0.054	0.036	< 0.2	< 0.09	< 18
	16	0.316	---	< 4	---	< 0.1	0.036	0.026	< 0.2	< 0.1	< 14
	17	0.189	---	< 2	---	< 0.2	0.027	0.010	< 0.1	< 0.5	< 21
	18	0.846	2.06	4.36	< 4	0.49	0.119	0.069	0.19	< 0.2	< 16
	19	0.217	< 0.9	1.38	< 3	< 0.2	0.027	0.018	< 0.2	< 0.2	< 23
	20	1.86	3.41	5.5	< 4	0.65	0.152	0.107	0.54	0.120	< 17
	21	8.70	18.7	33.9	14.5	4.49	0.89	0.586	2.48	0.28	< 16
	AVG TR1	1.05	4.38	6.06	---	1.04	0.114	0.073	0.631	0.152	---
A	4	4.95	13.6	19.8	< 19	2.73	0.556	0.366	1.54	0.201	< 18
J	47	12.5	30.8	50	< 25	7.4	1.51	0.993	4.19	0.544	< 8
	48	0.204	2.05	1.50	---	< 0.2	0.022	0.022	< 0.08	< 0.04	5.9
	49	0.501	5.08	3.4	---	< 0.2	0.054	0.037	0.14	< 0.1	< 5
	50	0.260	1.89	1.76	---	< 0.2	0.033	0.019	< 0.08	< 0.02	< 4
	51B	21.2	61.2	103	< 30	12.1	2.42	1.60	6.7	0.850	< 8
	AVG J	6.93	20.2	31.3	---	9.75	0.802	0.534	3.68	0.695	---

Table 3 (continued)

Core	Sample No.	S (%)	Hg (ppm)	Ash (%)	pH	Fe (%)	Na (%)	As (ppm)	Ba (ppm)	Br (ppm)	Co (ppm)	Cr (ppm)
I	38	4.40	0.02	28.5	4.50	0.121	6.3	25.4	323	< 700	0.347	6.7
	39	4.00	< 0.005	25.1	5.40	0.052	4.25	10.2	354	< 600	0.236	5.98
	40	4.60	< 0.005	31.9	5.30	0.356	5.11	7.2	222	< 700	0.92	35.8
	41	4.40	< 0.005	31.4	5.60	0.079	6.6	6.4	177	< 600	0.249	4.02
	42	5.20	0.02	33.6	5.50	0.102	5.4	5.5	359	< 500	0.68	5.6
	43	4.00	0.02	30.9	5.70	0.057	7.9	< 5	183	< 700	0.326	3.06
	44	3.80	< 0.005	35.5	4.00	0.072	11.0	9.0	270	1160	0.31	3.93
	AVG I	4.34	0.02	31.0	5.14	0.120	6.64	10.5	269	---	0.440	9.30
F	28	4.00	< 0.005	26.3	5.60	0.089	4.75	13.7	298	< 600	0.365	6.26
	29	4.20	< 0.005	37.5	5.60	0.204	8.7	7.5	330	1140	0.517	22.2
	30	4.30	0.010	34.8	5.70	0.043	6.0	5.4	118	< 600	0.154	2.78
	32	4.30	< 0.005	36.1	5.40	0.185	8.8	7.0	290	990	0.622	7.7
	33	3.80	< 0.005	33.8	5.50	0.060	7.24	5.2	260	< 600	0.312	2.66
	34	4.00	< 0.005	32.7	5.40	0.137	7.6	4.8	110	< 600	0.629	6.4
	35	4.00	< 0.005	41.4	5.10	1.09	8.1	6.1	<150	784	4.73	28.8
	AVG F	4.09	---	34.7	5.47	0.260	7.30	7.14	235	957	1.05	11.0
E	26A	2.70	< 0.005	73.1	7.30	2.52	3.5	22.9	140	314	7.70	75
D	18	4.00	< 0.005	31.2	6.70	0.078	5.5	6.5	290	< 600	0.309	7.6
	19	4.00	< 0.005	32.4	6.70	0.102	6.7	5.0	284	< 600	0.341	12.0
	20	4.10	< 0.005	32.7	7.20	0.036	6.8	5.3	148	< 600	0.122	3.12
	21	4.40	< 0.005	35.3	7.20	0.032	7.4	< 2	250	< 700	0.212	3.0
	22	4.00	< 0.005	26.3	6.30	0.024	9.6	< 3	124	< 700	0.419	1.16
	23	3.70	< 0.005	32.0	7.00	0.035	6.8	2.7	196	< 600	0.209	2.76
	24	5.00	0.03	29.1	6.10	0.045	6.3	< 2	21	< 500	0.384	2.49
	AVG D	4.17	---	31.3	6.74	0.0503	7.01	4.88	187	---	0.284	4.60
B	5	0.0800	< 0.005	68.8	7.50	0.140	4.18	3.9	160	621	0.275	9.9
	6	3.30	< 0.005	34.1	6.60	0.127	6.9	8.8	300	< 800	0.288	10.0
	7	3.80	< 0.005	31.6	6.40	0.072	6.2	3.4	270	< 800	0.248	6.14
	8	4.50	< 0.005	31.0	6.50	0.040	6.4	4.8	51	< 600	0.148	2.62
	9	4.20	< 0.005	37.2	6.50	0.040	8.2	< 2	300.	1010	0.335	3.45
	10	3.80	< 0.005	28.8	7.00	0.027	7.0	3.7	101	< 600	0.164	1.73
	11	5.10	< 0.005	43.0	7.40	0.319	7.0	3.2	< 220	783	2.08	6.7
	12	5.20	< 0.005	46.2	6.40	0.88	9.8	< 2	< 190	940	2.55	14.0
	13	4.20	< 0.005	80.9	3.80	4.33	2.06	21.1	120	189	11.0	94.7
	AVG B	3.80	---	44.6	6.46	0.664	6.42	6.97	192	708	1.89	16.6
TR3	35	6.00	< 0.005	15.2	4.5	0.032	6.6	7.8	507	962	0.331	4.67
	36	5.00	< 0.005	16.0	5.7	0.058	5.8	12.8	400	1160	0.714	9.0
	37	5.60	< 0.005	21.3	5.7	0.069	6.1	< 7	222	787	0.239	2.47
	38	5.50	< 0.005	23.8	5.2	0.115	5.3	9.2	107	769	0.33	6.81
	39	6.00	< 0.005	24.5	5.6	0.079	7.6	< 4	161	1010	0.355	4.98
	40	5.00	< 0.005	5.8	5.8	0.053	6.1	5.6	398	866	0.50	3.1
	41	5.20	< 0.005	22.9	5.7	0.087	3.5	< 9	146	647	1.69	4.39
	42	5.00	< 0.005	70.9	3.6	3.13	1.35	17.6	92	213	8.39	87.9
	43	4.10	< 0.005	78.8	3.1	4.32	0.76	18.2	84	94	9.28	104
	AVG TR3	5.27	---	31.0	5.0	0.882	4.80	11.9	236	723	2.43	24.8
C	15	0.790	< 0.005	45.8	7.60	0.061	7.0	8.5	< 210	940	0.247	4.39
	16	0.840	< 0.005	49.8	7.60	0.064	4.29	6.5	170	573	0.195	3.68
	17	3.00	< 0.005	35.4	7.70	0.061	7.5	4.7	280	850	0.279	7.4
	AVG C	1.54	---	43.7	7.63	0.062	6.27	6.57	225	787	0.240	5.17
	AVG All	4.25	0.0156	32.6	5.50	0.443	6.10	9.81	264	884	1.53	14.8

Table 3 (continued)

Core	Sample No.	Cs (ppm)	Hf (ppm)	Rb (ppm)	Sb (ppm)	Se (ppm)	Sr (ppm)	Ta (ppm)	Th (ppm)	U (ppm)	W (ppm)	Zn (ppm)
I	38	0.163	0.130	2.8	0.94	---	100	0.052	0.304	60	---	3.3
	39	0.106	0.063	2.4	0.423	---	109	0.029	0.198	61	---	2.1
	40	0.95	0.476	10.4	0.38	---	113	0.157	1.45	34	---	9.8
	41	0.086	0.081	1.54	0.262	---	116	0.026	0.157	31.7	---	2.43
	42	0.224	0.14	3.4	0.286	---	108	0.048	0.34	62	---	2.3
	43	0.077	0.067	2.6	0.103	---	124	< 0.03	0.196	33.4	---	2.1
	44	0.067	< 0.2	< 3	0.60	< 0.8	118	< 0.04	0.120	72	---	< 2
	AVG I	0.239	0.160	3.78	0.427	---	113	0.0630	0.389	50.6	---	3.67
F	28	0.155	0.104	1.4	0.326	---	144	0.048	0.264	54	---	2.1
	29	0.303	0.186	5.6	0.336	2.4	133	0.064	0.53	67	---	4.8
	30	0.027	< 0.1	1.8	0.202	---	134	< 0.03	0.126	19.4	---	2.0
	32	0.414	0.206	6.5	0.384	< 0.7	134	0.067	0.466	49	---	3.9
	33	0.069	0.053	1.5	0.180	---	110	< 0.04	0.204	43.9	---	3.3
	34	0.146	0.163	2.8	0.219	---	109	0.051	0.324	19.5	---	4.9
	35	1.59	1.31	14.8	0.52	< 0.7	130	0.269	2.93	15.2	---	28.0
	AVG F	0.388	0.336	4.94	0.310	---	126	0.100	0.687	38.1	---	7.0
E	26A	4.28	2.50	55	2.40	< 1	790	0.72	5.9	12.7	---	37.9
D	18	0.095	0.075	< 4	0.277	---	201	0.025	0.193	53	---	2.3
	19	0.184	0.143	2.9	0.237	---	269	0.046	0.277	47	---	9.7
	20	0.036	0.064	< 1	< 0.1	---	224	< 0.03	0.142	25.5	---	2.1
	21	0.063	< 0.05	< 3	0.104	---	245	0.031	0.117	41	---	2.4
	22	0.027	0.087	1.2	0.078	---	150	< 0.03	0.066	21.5	---	3.5
	23	0.050	0.075	< 1	0.114	---	252	< 0.03	0.103	35.7	---	5.2
	24	0.043	0.045	< 2	0.093	---	186	< 0.04	0.093	2.71	---	6.5
	AVG D	0.071	0.081	2.0	0.150	---	219	0.034	0.141	32.4	---	4.53
B	5	0.73	0.442	16.8	0.30	< 0.5	3260	0.109	1.56	7.9	---	8.3
	6	0.182	0.144	< 4	0.216	---	304	0.045	0.352	26.3	---	5.4
	7	0.069	0.083	2.8	0.192	---	202	< 0.03	0.182	39.1	---	6.4
	8	0.034	0.071	2.0	0.117	---	160	< 0.03	0.092	9.0	---	2.3
	9	0.105	0.089	< 3	0.205	< 0.6	185	< 0.04	0.177	67	---	2.4
	10	0.018	0.096	2.0	0.110	---	202	< 0.03	0.061	18.1	---	2.6
	11	0.234	0.234	< 5	0.179	< 0.7	250	0.039	0.50	14.8	---	8.1
	12	0.447	0.57	7.4	0.25	< 0.7	207	0.107	1.14	14.6	---	13.6
	13	7.6	5.26	61	2.78	1.8	113	1.26	14.2	7.4	---	61.6
	AVG B	1.05	0.775	15.4	0.487	---	547	0.313	2.03	22.7	---	12.3
TR3	35	0.041	0.045	2.0	0.336	1.83	139	0.020	0.095	83	---	2.2
	36	0.202	0.180	3.4	0.214	1.86	145	0.050	0.412	66	---	2.9
	37	< 0.01	0.145	< 2	0.185	1.08	137	< 0.02	0.074	37	---	2.10
	38	0.119	0.187	2.3	0.160	1.68	121	0.030	0.258	18.0	---	2.99
	39	0.051	0.101	2.3	0.21	1.63	120	< 0.04	0.131	25.4	---	2.69
	40	< 0.05	0.039	1.5	0.197	1.23	118	< 0.02	0.095	62	---	5.8
	41	< 0.03	0.169	< 3	0.234	0.73	78	< 0.02	0.079	19.2	---	3.1
	42	7.42	5.28	50.1	2.14	0.93	67	1.28	14.8	2.8	---	64
	43	8.1	6.15	56	1.26	0.73	89	1.39	16.6	2.6	---	66
	AVG TR3	2.66	1.37	16.8	0.548	1.30	113	0.56	3.62	35	---	16.9
C	15	0.079	0.064	2.1	0.49	< 0.6	1290	0.037	0.117	36	---	2.2
	16	0.046	0.074	1.6	0.229	0.58	1820	< 0.03	0.107	31.8	---	2.5
	17	0.083	0.073	2.1	0.41	< 0.8	332	< 0.04	0.147	64	---	3.1
	AVG C	0.069	0.070	1.9	0.377	---	1143	---	0.127	44.0	---	2.6
	AVG All	0.787	0.571	9.46	0.466	1.59	219	0.194	1.37	41.2	---	9.38

Table 3 (continued)

Core	Sample No.	Sc (ppm)	La (ppm)	Ce (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Tb (ppm)	Yb (ppm)	Lu (ppm)	Au (ppb)
I	38	0.407	4.77	3.3	---	< 0.2	0.045	0.032	< 0.1	< 0.2	< 5
	39	0.266	4.76	3.1	< 0.2	< 0.2	0.029	0.020	< 0.4	< 0.2	< 4
	40	2.16	8.6	10.3	< 2	1.19	0.278	0.184	0.83	0.094	9.6
	41	0.199	2.63	1.67	---	< 0.2	0.031	0.020	< 0.3	< 0.07	< 6
	42	0.497	5.48	3.7	---	< 0.2	0.059	0.036	0.16	< 0.1	< 5
	43	0.227	3.25	1.70	< 0.6	< 0.3	0.0360	0.0190	< 0.0900	< 0.0700	< 5
	44	0.157	4.51	< 5	< 30	< 0.2	0.041	0.017	< 0.6	< 0.03	< 15
	AVG I	0.560	4.87	3.92	---	---	0.0743	0.0463	0.495	---	---
F	28	0.357	3.91	3.3	---	< 0.2	0.047	0.036	0.15	< 0.1	< 4
	29	0.82	5.00	< 5	< 12	< 0.2	0.108	0.074	< 0.6	0.031	< 14
	30	0.113	2.22	1.75	---	< 0.2	0.027	0.020	< 0.08	< 0.05	< 4
	32	0.75	4.42	< 5	< 14	0.18	0.055	0.0454	< 0.7	< 0.02	< 13
	33	0.167	3.94	2.65	---	< 0.2	0.031	0.022	< 0.1	< 0.1	< 5
	34	0.397	2.52	2.1	< 0.3	< 0.2	0.048	0.031	0.17	< 0.04	< 4
	35	4.04	11.6	17.7	< 18	2.26	0.454	0.307	1.23	0.193	< 12
	AVG F	0.949	4.84	5.56	---	1.24	0.110	0.0770	0.507	0.111	---
E	26A	7.64	18.7	28.3	< 12	3.74	0.780	0.516	2.00	0.283	< 7
D	18	0.276	3.47	2.5	---	< 0.2	0.043	0.019	< 0.09	< 0.1	< 4
	19	0.460	3.66	3.0	---	< 0.2	0.053	0.040	0.18	< 0.1	< 4
	20	0.131	2.07	1.3	---	< 0.2	0.038	0.020	< 0.08	< 0.07	< 5
	21	0.133	2.91	1.6	< 0.6	< 0.2	0.019	< 0.005	< 0.09	< 0.1	< 5
	22	0.048	1.67	0.97	< 1.1	< 0.2	0.016	0.017	< 0.09	< 0.06	< 5
	23	0.134	2.63	1.53	---	< 0.2	0.032	0.021	< 0.08	< 0.1	6.7
	24	0.098	1.27	1.28	< 2	< 0.1	0.021	< 0.007	0.14	< 0.009	< 4
	AVG D	0.182	2.54	1.74	---	---	0.0317	0.0234	0.160	---	---
B	5	0.81	5.03	6.5	< 40	0.78	0.145	0.100	0.51	0.066	< 10
	6	0.527	3.10	2.9	< 4	0.28	0.084	0.044	0.16	< 0.08	< 4
	7	0.258	2.56	2.2	< 0.3	< 0.2	0.034	0.033	< 0.09	< 0.1	< 4
	8	0.145	1.00	0.97	< 0.3	< 0.1	0.027	< 0.02	< 0.2	< 0.03	< 4
	9	0.26	3.35	< 3	< 26	< 0.2	0.035	0.022	< 0.7	< 0.03	< 14
	10	0.065	1.29	0.91	---	< 0.2	0.018	< 0.009	0.14	< 0.06	< 4
	11	0.65	1.84	2.1	< 23	0.22	0.075	0.041	< 0.5	0.058	< 14
	12	1.39	3.05	4.6	< 28	0.64	0.155	0.099	1.3	0.079	< 14
	13	14.1	33.9	59.9	< 30	7.60	1.52	1.04	4.34	0.549	11
	AVG B	2.02	6.11	10.0	---	1.90	0.233	0.197	1.28	0.188	---
TR3	35	0.157	---	< 3	---	< 0.3	0.019	< 0.01	< 0.2	< 0.8	< 27
	36	0.574	---	2.5	---	< 0.3	0.064	0.044	0.22	< 0.6	< 18
	37	0.083	---	< 2	---	< 0.2	0.022	0.014	< 0.1	< 0.3	< 16
	38	0.335	---	< 3	< 3	0.16	0.037	0.027	< 0.1	< 0.3	< 19
	39	0.169	< 1	< 2	< 2	< 0.3	0.023	0.016	< 0.1	< 0.3	< 17
	40	0.087	---	< 5	---	< 0.2	0.015	0.017	< 0.2	< 0.6	< 17
	41	0.227	1.70	2.3	< 2.10	< 0.3	0.027	0.017	< 0.2	< 0.04	< 21
	42	13.9	32.5	57.6	19.9	6.71	1.37	0.992	3.76	0.56	< 10
	43	18.1	45.7	78.5	25.7	9.2	1.80	1.23	4.9	0.71	< 4
	AVG TR3	3.74	26.6	35.2	22.8	5.35	0.375	0.295	2.97	0.64	---
C	15	0.18	2.68	< 3	< 16	< 0.1	0.041	0.030	< 0.5	< 0.01	< 14
	16	0.126	2.50	< 2	< 15	< 0.1	0.034	0.023	< 0.4	< 0.02	< 11
	17	0.211	3.75	< 3	< 10	< 0.2	0.030	0.025	< 0.5	< 0.02	< 14
	AVG C	0.173	3.00	---	---	---	0.0350	0.0260	---	---	---
	AVG All	1.63	7.30	9.89	20.0	2.26	0.179	0.128	1.16	0.281	8.3

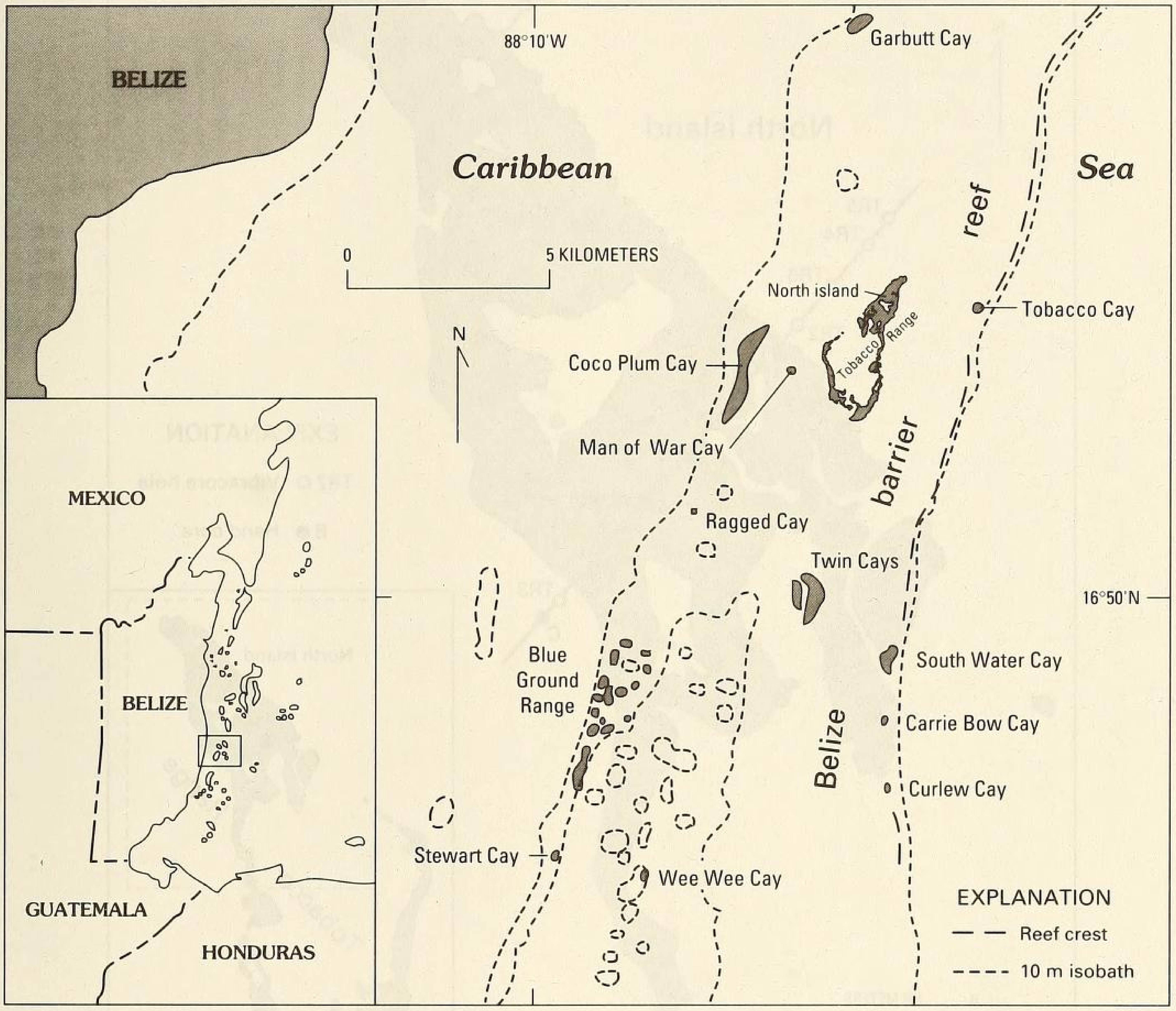


Figure 1. Location of Tobacco Range on the Belize barrier reef. Taken from Woodroffe (1995, this volume)

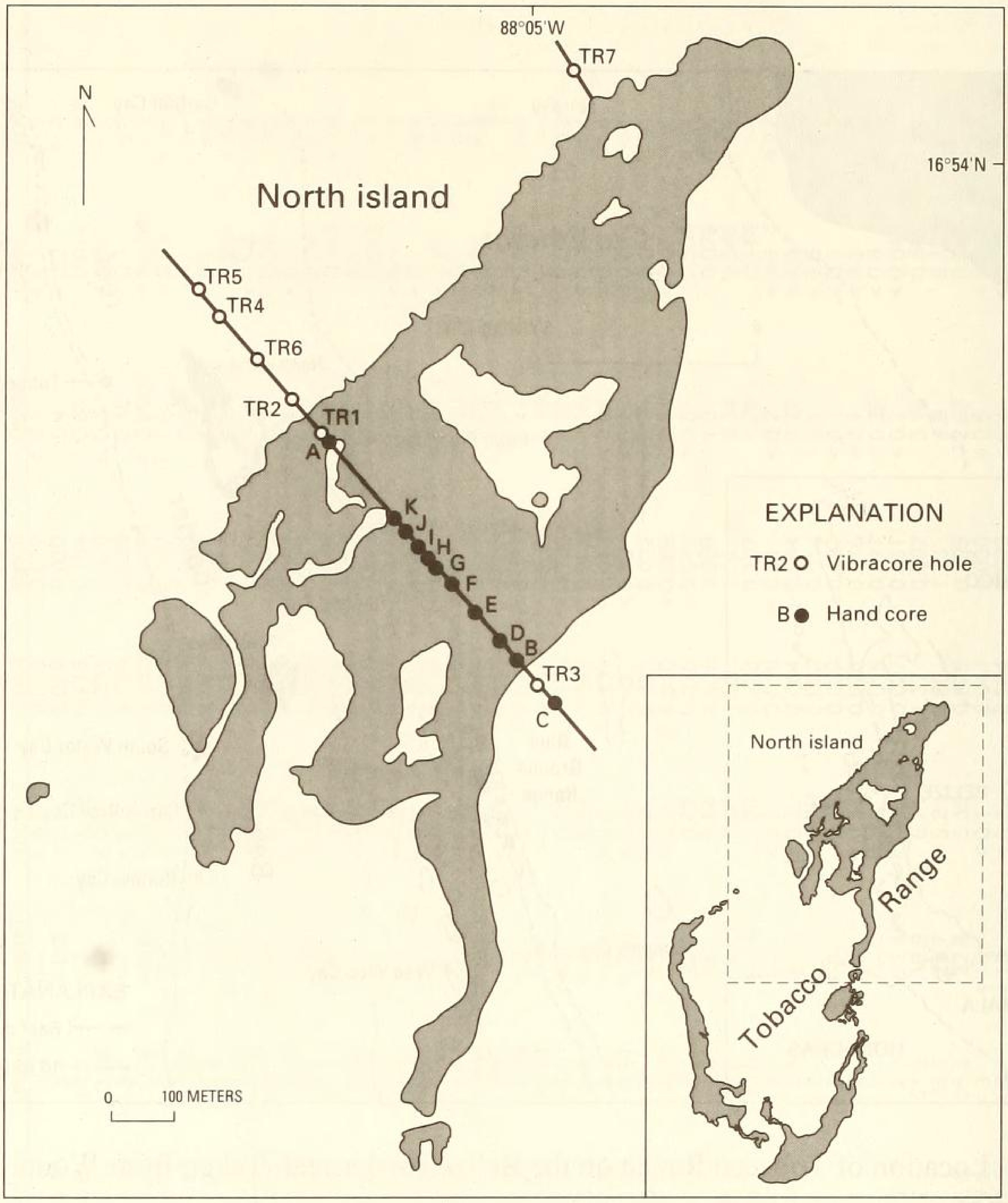


Figure 2. Northwest-southeast traverse across the north island of Tobacco Range showing location of cores. Taken from Macintyre et al. (1995, this volume)

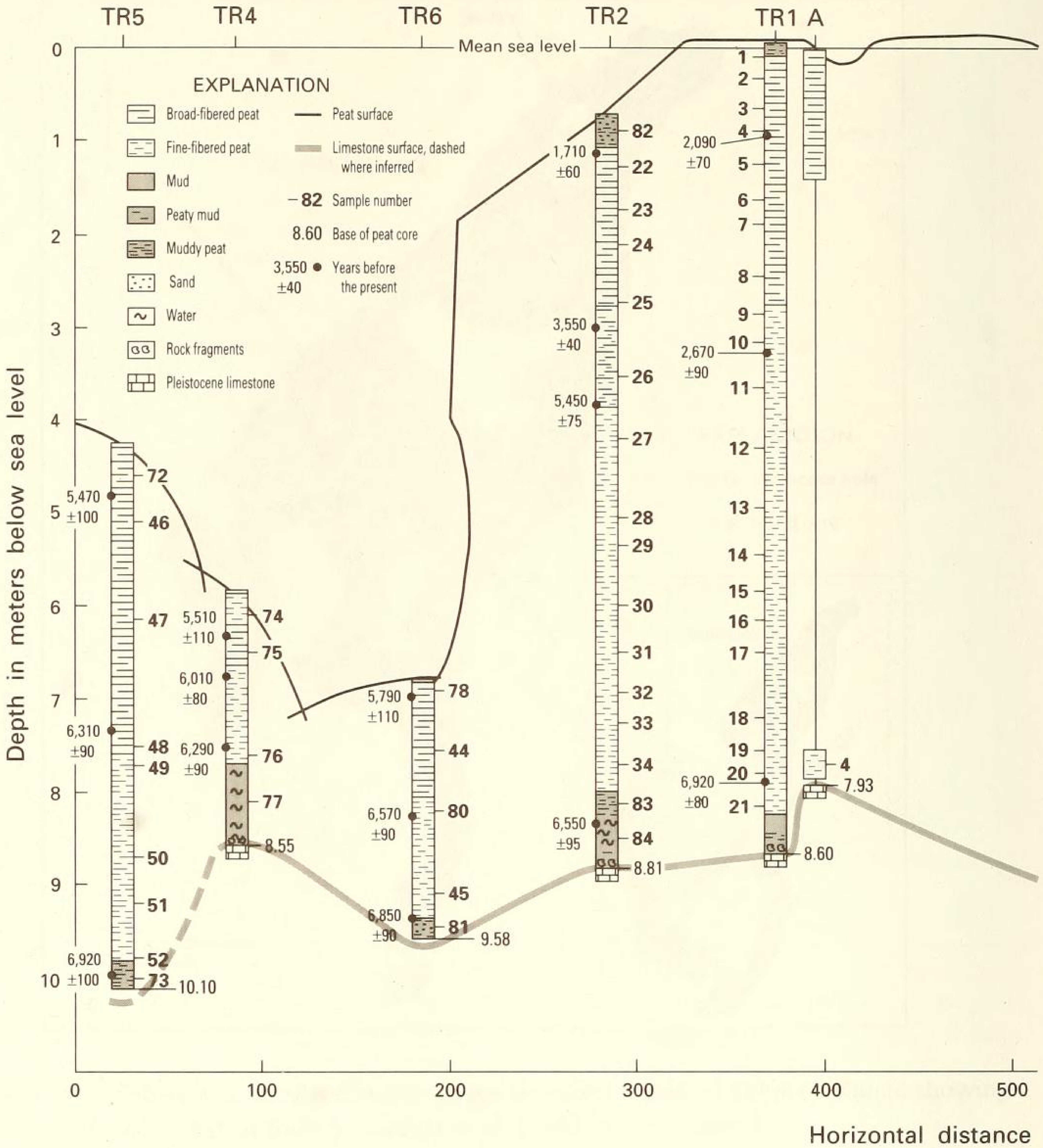
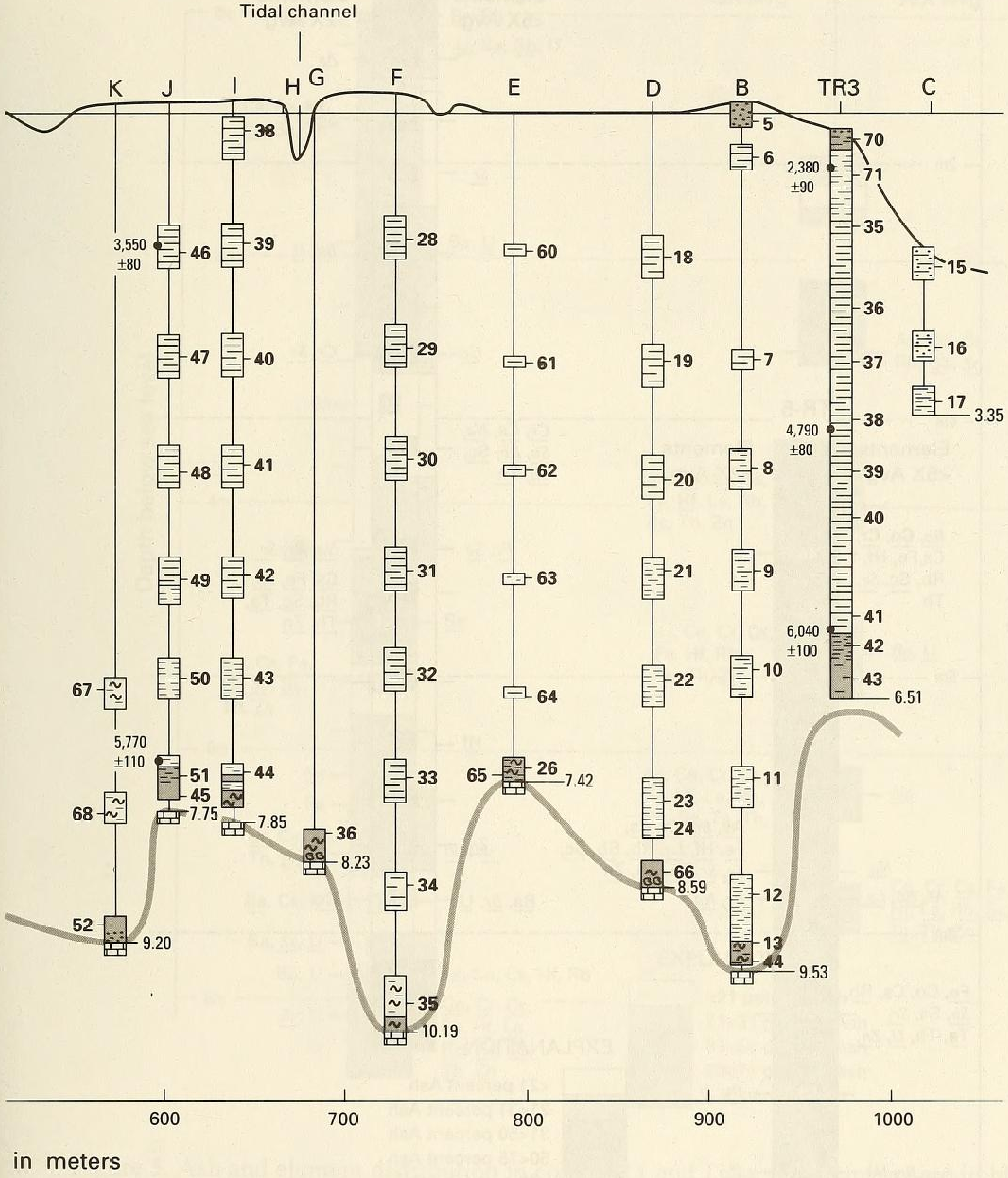


Figure 3. Cross section through the northwest-southeast traverse of Tobacco Range. Taken from Macintyre et al. (1995, this volume)


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

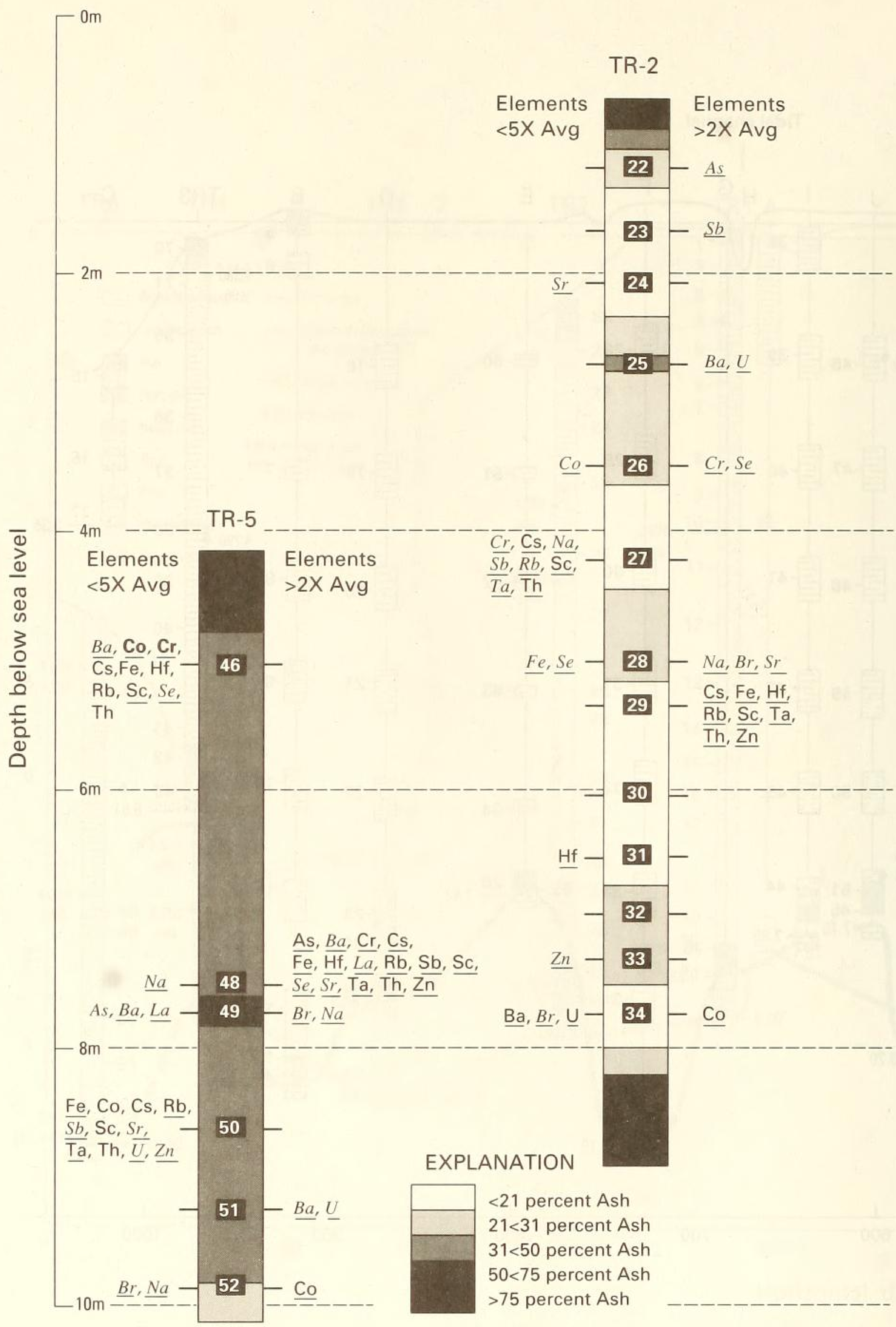


Figure 4. Ash and element distribution in cores TR5 and TR2. Sample numbers are in black squares. Ranges of dry ash contents are represented by patterns. Underlined element symbols are listed for samples with the highest (to the right) or lowest (to the left) concentration of each element in cores TR5 and TR2. Concentrations of elements listed are less than 5 times the average core concentration or greater than 2 times the core average except for elements listed in italics which do not meet those criteria but have the highest or lowest concentrations in the core.

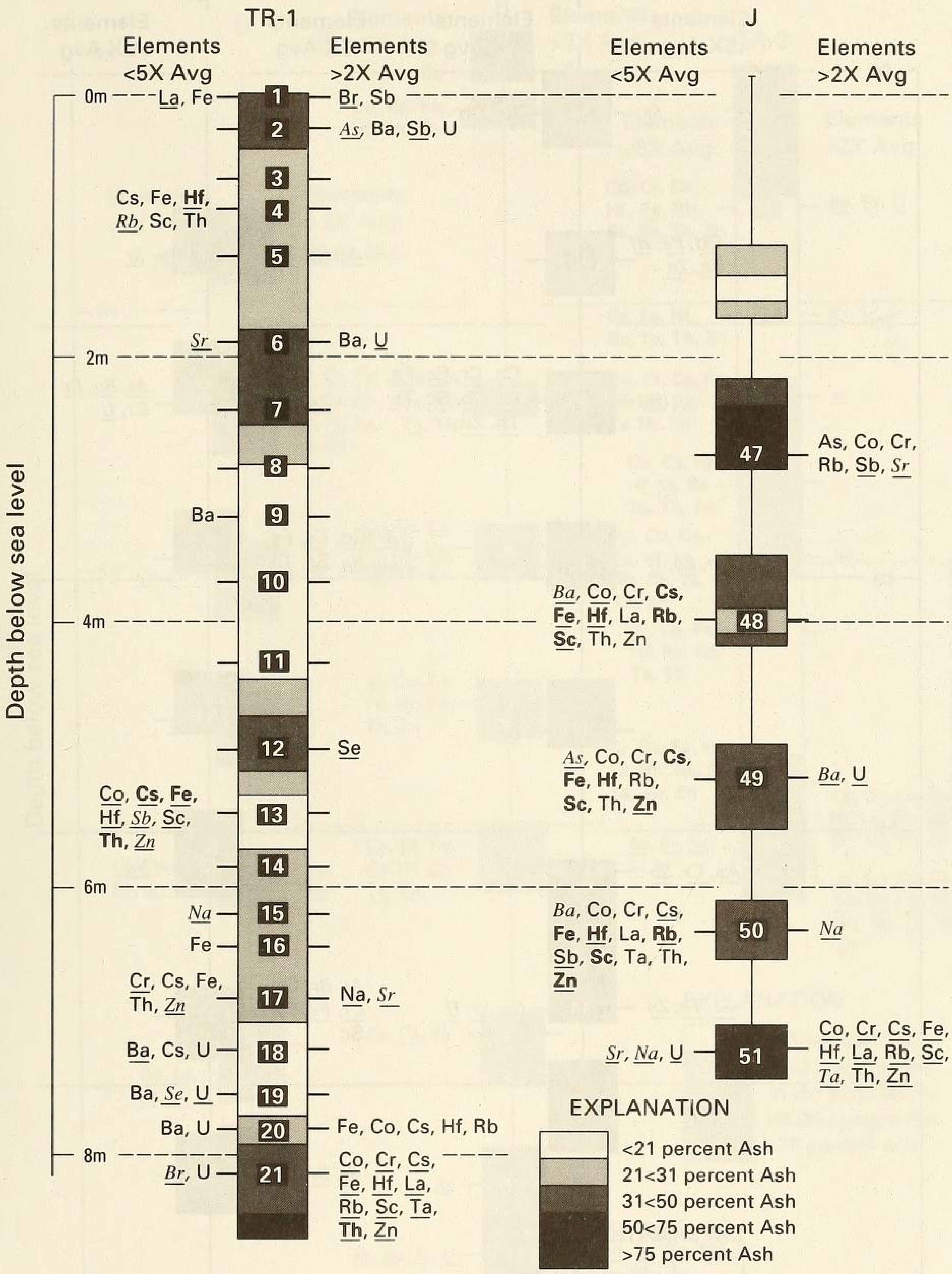


Figure 5. Ash and element distribution in cores TR1 and J. Sample numbers are in black squares. Ranges of dry ash contents are represented by patterns. Underlined element symbols are listed for samples with the highest (to the right) or lowest (to the left) concentration of each element in cores TR1 and J. Concentrations of elements listed are less than 5 times the average core concentration or greater than 2 times the core average except for elements listed in italics which do not meet those criteria but have the highest or lowest concentrations in the core. Elements in bold are greater or less than ten times the average.

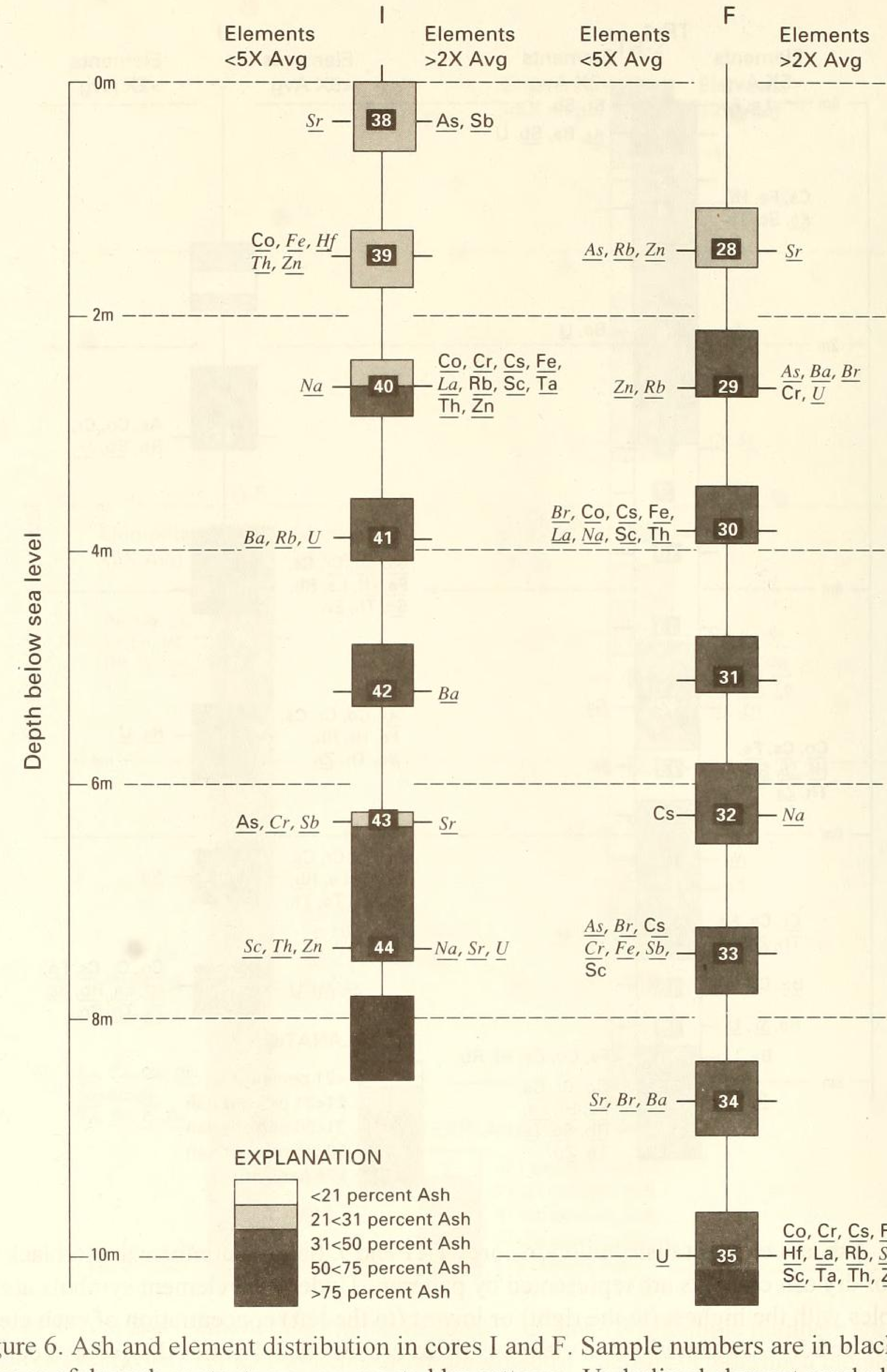


Figure 6. Ash and element distribution in cores I and F. Sample numbers are in black squares. Ranges of dry ash contents are represented by patterns. Underlined element symbols are listed for samples with the highest (to the right) or lowest (to the left) concentration of each element in cores I and F. Concentrations of elements listed are less than 5 times the average core concentration or greater than 2 times the core average except for elements listed in italics which do not meet those criteria but have the highest or lowest concentrations in the core.

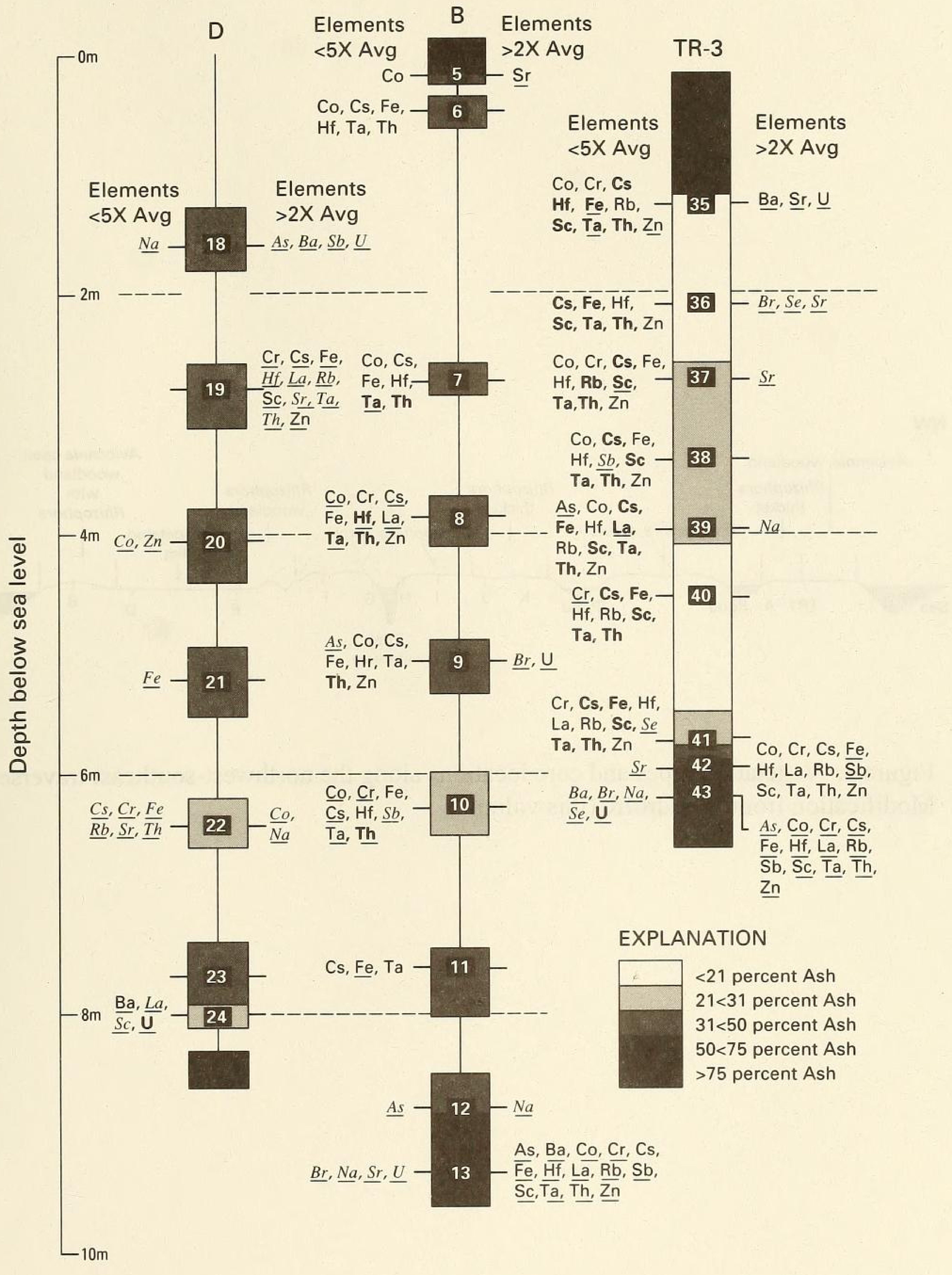


Figure 7. Ash and element distribution in cores D, B and TR3. Sample numbers are in black squares. Ranges of dry ash contents are represented by patterns. Underlined element symbols are listed for samples with the highest (to the right) or lowest (to the left) concentration of each element in cores D, B and TR3. Concentrations of elements listed are less than 5 times the average core concentration or greater than 2 times the core average except for elements listed in italics which do not meet those criteria but have the highest or lowest concentrations in the core.

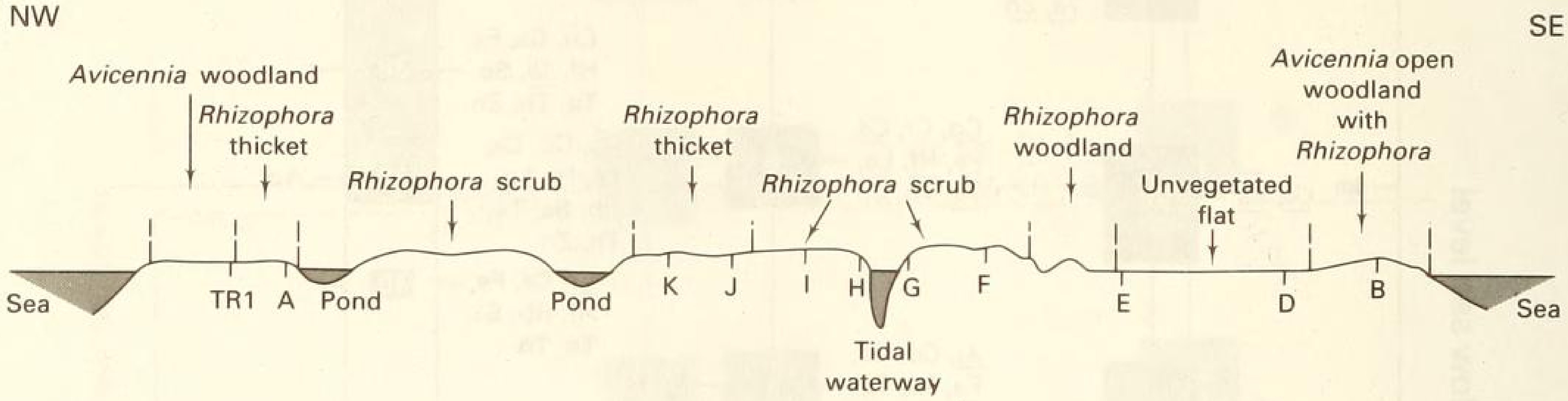


Figure 8. Vegetation types and core locations along the northwest-southeast traverse. Modification from Woodroffe (this volume)