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ROAD LOG AND DOCUMENTARY PHOTOGRAPHS FOR 15 SIGNIFICANT BIOSTRATIGRAPHIC SITES IN MIOCENE-PLIOCENE LIMESTONE, KINGSHILL SEAWAY, ST. CROIX, U.S. VIRGIN ISLANDS

by

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Detailed examination of planktonic Foraminifera from the type section of the Miocene Kingshill Limestone and from 14 other Miocene and lower Pliocene limestone exposures in the Kingshill Seaway of St. Croix (lat 17°44' N., long 64°46' W.; fig. 1) has led to the first publication of an in-depth biostratigraphic investigation of this area with application of the most up-to-date zonation and ecological principles. In addition, scanning electron micrographs of all identified species, subspecies, and significant paleoenvironmentally representative aberrant forms from the region have been published for the first time. Because of the importance of this work, and of the extensive diagenetic alteration of the hemipelagic deposits, as well as density of plant cover on available exposures, precise documentation of each location studied was essential. Thus, a road log was constructed (Appendix 1), in conjunction with documentary pace-and-compass readings and vertical measurements within a section to actual area of collection. Aerial plus wide-angle and normal land photographs were also taken in order to facilitate accurate relocation of all sample sites by future workers.

In Miocene time, St. Croix consisted of two small islands with fringing reefs, separated by an open seaway. Pelagic sediments accumulated in this depression between the islands in layers approximately 10-20 cm thick, alternating with thin ash-fall beds (presumably volcanic), distal carbonate turbidites, and occasional thick mass-displacements of reefal and terrigenous rubble. Sedimentary layers dip gently (less than 15°) to the south throughout the seaway, indicating absence of tectonic stress other than uplift, which has taken place since deposition.

Planktonic Foraminifera (table 1) indicate that, from the north-central to southwest coasts, these rocks range sequentially in age from the mid-middle Miocene to the lower Pliocene, as defined by the *Globorotalia fohsi* Zone (N12) and the *Sphaeroidinella dehiscens*/*Globoquadrina altispira* Zone (N19). Based on the pelagic specimens identified, water depth in the basin was at least 200 m and may have reached 700 m. A warm, nutrient-rich, regressive environment, favorable for high pelagic biogenic skeletal productivity, apparently existed until some time within the late Miocene when conditions began to deteriorate, possibly in response to the onset of severe Antarctic glaciation (Ciesielski and others, 1981) or to the more restricted influence of volcanic activity, upcurrent and upwind, on the Antillean Island Arc chain (Westercamp and Tomblin, 1979). Regardless of the cause, a marked degradation of water quality was recorded globally in the ancient seas at this time and is marked as such by the common occurrence of aberrant phenotypic Foraminifera (Lidz, 1972; Malmgren and Kennett, 1976). Locally, the Antarctic crisis may have precipitated a cooling of ocean temperatures commensurate with a drop in sea level and ultimate regression of the sea from the St. Croix basin. The ash-fall layers prevalent in the approximately 320-m-long type section sequence at Ville la Reine (Station 7), however, are also evidence for a series of episodic events that must have been a contributing factor to the deterioration of optimum environment in the area.

Identification of species and subspecies was possible only from 38 of 55 samples collected from the 15 stations. This resulted in an age determination with resolution to foraminiferal zone for nine stations (fig. 2). Descriptions of all exposures studied are summarized in Appendices 1-3. Foraminiferal zones assigned and corresponding portions of the Miocene or Pliocene are presented in table 2, as well as interpreted environments of deposition for all stations. Figures 1 and 3-22 are the documentary land and aerial photographs for these significant biostratigraphic locations.

TABLE 1. Tabulation by station of pelagic Foraminifera identified from St. Croix

Species	Station Number 4	5	6	7	8	9	10	11	12
Candeina nitida				X		X			
Globigerina bulloides						X	X		
G. foliata	X		X						
G. nepenthes			X	X	X	X*	X	?	X
G. praebulloides	X								
G. quinqueloba			X			X*	X		
G. venezuelana	X		X			X	X	X	X
Globigerinita humilis						X*	X		
Globigerinoides conglobatus						X	X	X	?
† *G. diminutus*									
G. mitra	X					X*			
G. obliquus extremus						X	X	X	X
G. obliquus obliquus	X		X	X		X	X	X	X
G. ruber	X					X	X	X	X
G. sacculifer	X		X	X	X	X	X	X	X
G. subquadratus	X								
G. trilobus	X		X	X		X	X	X	X
Globoquadrina altispira	X		X	X	X	X	X	X	X
G. dehiscens	X		X	X	X	X*			
Globorotalia acostaensis						X	X		X
† *G. archeomenardii*									
G. crassaformis						X	X		
G. crassula						X	X		
G. fohsi fohsi	X								
G. fohsi lobata	X								
G. humerosa				X		X	X	X	X
G. mayeri	X	X	X						
G. menardii				X		X*	X	X	X
G. miocenica						X*	X	X	X
G. multicamerata						X	X	X	X
G. obesa						X	X		
G. plesiotumida				X		X*	X	X	X
G. praemenardii	X	X	X						
G. scitula	X		X		X	X	X		
G. siakensis	X		X						
G. tumida						X	X	?	X
Hastigerina aequilateralis				X	X	X	X	X	
H. siphonifera	X			X		X	X		
Orbulina bilobata	X		X		X				
O. suturalis	X				X	X	X		
O. universa	X		X	X	X	X	X	X	X
† *Pulleniatina obliquiloculata*									
† *Sphaeroidinella dehiscens*									
Sphaeroidinellopsis seminulina	X		X	X		X*	X	X	
S. subdehiscens paenedehiscens				X		X*		X	
S. subdehiscens subdehiscens				X	X	X		X	

* Species found only in the lower 6.6 m, which represent the Kingshill Limestone, at Evans Highway roadcut (Station 9).

† Significant species not identified from the samples examined.

TABLE 2. Summary by individual stations of primary rock type (according to Dunham, 1962), planktonic foraminiferal zone assigned (where determined), equivalent epoch age, and suggested interpretations for environments of deposition

Station	Limestone Rock Type	Foraminiferal Zone	Epoch Age	Suggested Interpretations for Environments of Deposition
1, 2	Molluscan packstone	---	---	Low-energy lagoonal or shoal shelf (up to about 50 m)
3	Molluscan packstone	---	---	High-energy reef or patch reef (50-100 m)
4	Foraminiferal grainstone	N12	mid-middle Miocene	Outer shelf edge (100-200 m) or upper slope (200-500 m) with distal pelagic turbidites
5	Lithoclastic wackestone-packstone	N10-N12	mid-middle Miocene	Outer shelf edge or upper slope with terrigenous turbidites
6	Bioclastic grainstone	N14	late middle Miocene	Proximal deep-water fan (200-500 m) with terrigenous turbidites & older pelagics
7	Polymictic grainstone	N17	late Miocene	Upper slope or basin floor (500-700 m) on distal deep-water fan with cut-and-fill structures, ash layers, terrigenous turbidites, and slump deposits
8	Foraminiferal wackestone	N13-N18	middle thru late Miocene	Upper slope or basin floor with pelagic turbidite
9	Bioclastic mud-wacke-pack-grainstone	bottom N18 + top N18 and/or N19	latest Miocene + early Pliocene	Basin floor distal submarine fan with channel debris
10, 11	Bioclastic mudstone	top N18 and/or N19	early Pliocene	Low-energy, shallow shelf, upper slope or basin floor hardgrounds
12	Bioclastic grainstone	top N18 and/or N19	early Pliocene	Low-energy *in situ* barrier reef or shallow shelf reef (less than 20 m) with soilstone crusts and karst features
13	Bioclastic grainstone	---	---	Low-energy reef shoreward of Station #12
14	Pelletal mudstone	---	---	Low-energy shelf lagoon shoreward of Station #15
15	Pelletal grainstone	---	---	Low-energy inshore reef(?) (less than 20 m)

APPENDIX 1

Road Log and Brief Description of Biostratigraphic Sites Following Route Marked on Aerial Photomosaic

Mileage mi (km)	Cumulative Mileage mi (km)	
0.00	0.00	Start log on unpaved road leading south from Salt River estuary at telephone poles and single-chain gate marking south boundary of and entrance to Faile Estate (fig. 1). Proceed south 0.23 mi and stop.
0.23 (0.37)	0.23 (0.37)	Station #1. Sample site approximately 18 m above mean sea level (MSL) on west side of road in middle portion of lowest exposure of Miocene sediments overlying older (Oligocene?) volcanics exposed in roadbed. Molluscan packstone outcrop about 1 m above roadbed heavily overgrown with Acacia bushes. Surface weathered gray, fresh cuts white, well cemented. Organic components: molluscan, echinoderm, bryozoan, and coral fragments, benthic Foraminifera. Continue south and east on unpaved main road 0.17 mi to juncture with paved driveway. Stop.
0.17 (0.27)	0.40 (0.64)	Station #2. Walk to sample site approximately 46 m above MSL and 18 m downhill on south side of private driveway heading east. Sampled within concave upper portion of 5-m outcrop of well-cemented molluscan packstone forming central high in residential turnabout. Exposure surface deeply pitted, blackened by Holocene algae, sparsely vegetated. Fresh cuts white. Moldic porosity. Organic components: bryozoan, echinoderm, coral, and molluscan fragments. Return to vehicle at road junction.
0.00	0.40 (0.64)	Station #3. Walk to sample site approximately 49 m above MSL on west side of main dirt road and about 14 m south of juncture with paved driveway. Sample collected about 1 m up from road in semi-friable, brown, oxidized, molluscan packstone. Sparry calcite coats debris. Porosity about 15-20%. Organic components: benthic and pelagic Foraminifera (benthic specimens predominate), coral debris, molds of molluscs, gastropods, coral calices, worm tubes, echinoderm and *Halimeda* fragments. Return to vehicle and drive south, away from Salt River estrary, to junction with two paved main roads. Cross east-west road to Queen's Quarter Road and continue south to 1.00 mi from last stop. Stop.

Mileage	Cumulative Mileage	
1.00 (1.60)	1.40 (2.24)	Station #4. Approximately 85 m above MSL, "Hill House" outcrop of foraminiferal grainstone on southeast side of first bend in road may be concealed by tall grass growing at base. Horizontal laminated, fine-grained, unconsolidated pelagic layers alternate with hardbeds representing distal turbidites. Sample site approximately 1.5 m above roadbed within first friable layer beneath massive, undifferentiated bed. Color beige. Dip bearing 150° at 5°. Organic components: about 98% pelagic specimens, 2% benthic specimens plus ostracods and coralline algae. Benthic specimens small and delicate.
		Continue south on Queen's Quarter Road 0.47 mi to juncture with Rattan Road to the east. Turn left (east) and proceed northeast, uphill 0.25 mi on Rattan Road past Danish sugar mill ruins on left. Stop at juncture with paved private driveway on east side.
0.72 (1.15)	2.12 (3.39)	Station #5. Walk about 20 m north along west side of Rattan Road to a 2-m roadside outcrop of highly cemented, chalky, lithoclastic wackestone-packstone and interbedded turbidites containing Cretaceous pebbles. Approximately 155 m above MSL, site heavily overgrown with thick brush and trees. Dip bearing 195° at 10°. Sample collected from within lower 1 m beneath turbidite debris. Organic components: echinoid spines, coral and mollusc debris, benthic and pelagic Foraminifera.
		Return to vehicle.
0.00	2.12 (3.39)	Station #6. Cross to east side of Rattan Road and walk to sample site. Approximately 146 m above MSL, 6-m exposure of bioclastic grainstone is about 40 m down a steep, paved private driveway ("New House" cut). White, 5-cm-thick beds are composed of interbedded terrigenous pebble (Cretaceous?) conglomerates and pelagics, indicating a proximal deep-water fan environment. Dip bearing 085° at 10°. Collection site about 3 m above base of drive in uncemented layer with negative relief. Excellent preservation of primarily pelagic Foraminifera, some benthic specimens and echinoid spines.
0.25 (0.40)	2.37 (3.79)	Return to vehicle, turn around, and proceed southwest on Rattan Road back to Queen's Quarter Road.
1.85 (2.96)	4.22 (6.75)	Turn left (south) on Queen's Quarter Road and drive 1.85 mi to junction with Centerline Road. Turn right on Centerline Road and drive west, past Superfood Warehouse (on right), Bank of America (left), and Estate Strawberry housing development (right).
1.64 (2.62)	5.86 (9.37)	Note roadcut exposures on right and left at top of hill overlooking Ville la Reine shopping center. Exposures form uppermost portion of Ville la Reine Kingshill Limestone

Mileage	Cumulative Mileage	
		and are composed of well-displayed submarine channel fills with interbedded pelagic deposits.
		Continue downhill to shopping center. Turn right into center and right again along south side of Pueblo Food Market. Drive east to rear of shopping center, turn left and stop at south end of exposure.
0.21 (0.34)	6.07 (9.71)	Station #7. Approximately 55 m above MSL, type section of Kingshill Limestone extends 23 m above roadbed and about 320 m (0.20 mi) long. Exhibiting deep-sea fan cut-and-fill structures in slump-filled channels containing coralline debris and pebbles interbedded with volcanic ash and pelagic deposits, overall type section is polymictic packstone. Sample collected from recessed pelagic layer about 1 m above lawn area and about 4 m north of massive debris flow deposit at south end of exposure. Sample composed of estimated 40% reef and allochthonous terrigenous turbidites and slump debris, 40% pelagic Foraminifera, and 20% benthic Foraminifera plus micromolluscs (*Caecum?*). Foraminifera are thin walled, fragmented, diagenetically altered and oxidized.
0.50 (0.80)	6.57 (10.51)	Return to front of Pueblo Food Market. (0.50 mi marked by driving length of exposure and back to south end.)
		Depart Ville la Reine shopping center and proceed 0.10 mi to crossroads junction with Centerline Road. Turn right (west) on Centerline Road and drive 0.40 mi to crossroads junction at Kingshill Lutheran Church.
0.50 (0.80)	7.07 (11.31)	Turn right (north) and proceed past cemetery and old slave quarters on left to unpaved road south of Fredensborg housing project.
0.40 (0.64)	7.47 (11.95)	Turn left (west) on dirt road and keep to left, going uphill, to enter rock quarry.
0.20 (0.32)	7.67 (12.27)	Station #8. Approximately 61 m above MSL, massive horizontal, cemented pelagic beds alternate with thinner, more cemented pelagic layers. Single, 18-cm-thick, brown, planktonic Foraminifera-rich turbidite deposit may represent period of non-deposition of shallow-water debris. Color of deep-sea deposits white to tan with oxidized staining. Sparry calcite infills fragmented, matrix-coated Foraminifera in the bioclastic wackestone. No other organic components are present.
		Complete circular drive clockwise in quarry and depart on dirt entrance road.
0.70 (1.12)	8.37 (13.39)	Return south 0.70 mi to Kingshill Lutheran Church and juncture with Centerline Road. Cross Centerline Road and continue south past Central High School (on right).

Mileage	Cumulative Mileage	
0.80 (1.28)	9.17 (14.67)	Juncture with Melvin Evans Highway and entrance to Martin Marietta Bauxite Processing Plant. Turn right (west) on Evans Highway and continue past stop lights.
1.75 (2.80)	10.92 (17.47)	Continue to "Signal Ahead" sign on left.
0.05 (0.08)	10.97 (17.55)	Continue to "Crossroads" sign on left and stop.
		<u>Station #9</u>. Approximately 24 m above MSL on south side of Evans Highway and just west of Manning, vertical sample site within estimated 300-m-long roadcut is about 33 m east from "Crossroads" sign and 25.5 m west from "Signal Ahead" sign, which is abeam of median divider overhead street light. Alternating horizontal hardbeds and pelagic chalks with distal channel deposits compose exposure. Dip bearing 200° at 6°-8°. Exposure at sample site measures 57'2" (17.4 m) upslope with calculated vertical thickness of 14.3 m. See Appendix 2 for detailed descriptions of 19 layers sampled.
1.10 (1.76)	12.07 (19.31)	Continue west on Evans Highway until first set of stop lights. Turn around and head east 1.10 mi on Evans Highway to next set of stop lights.
		Continue east 0.15 mi to just beyond "Keep to Left Except to Pass" sign and stop.
0.15 (0.24)	12.22 (19.55)	<u>Station #10</u>. Approximately 34 m above MSL, massive white and weathered-gray, amorphous hardgrounds of bioclastic mudstone, showing variable cementation producing clay pockets and friable beds which alternate with chertified limestone, form large exposures on both sides of road. Near-vertical sample site within 3 m above road at west end of south outcrop (on right as you drive). Secondary porosity indicated by calcite in leached vugs. Organic components include pelagic Foraminifera in fine fraction, plus shell hash, coral, worm tube, bryozoan, and coralline algae fragments, gastropod casts, *Halimeda* plates, micromolluscs (*Caecum*), echinoid spines, ostracod valves, and alcyonarian spicules in about 90% coral debris.
		Continue east 0.45 mi and stop.
0.45 (0.72)	12.67 (20.27)	<u>Station #11</u>. Approximately 27 m above MSL, smaller exposures of massive, highly cemented hardgrounds, similar in color, organic content, and rock texture to those at Station #10, occur on both sides of road. Sample site in north exposure (on left as you drive) at base near roadbed.
		Proceed east along Evans Highway 0.40 mi to stop lights at entrance to Martin Marietta Processing Plant. Continue

Mileage	Cumulative Mileage	
		east, past Krause Great House ruins (on right) at 0.20 mi, to entrance of unpaved access road separating Martin Marietta Plant and Amerada Hess Refinery. Turn right (south) and proceed 0.95 mi downhill to south end of Hess roadcut. Turn around.
1.55 (2.48)	14.22 (22.75)	Station #12. Approximately 34 m above MSL, roadcut exposure extends about 300 m along west (left) side of road. Lighter colored material, representing ancient sea floors, alternates with darker, algae-coated debris flow deposits. See Appendix 3 for sample and barrier reef-site descriptions for 12 samples collected. Proceed north, uphill along Hess access road. Note karst pits and soilstone crusts about 3 m above roadbed.
0.15 (0.24)	14.37 (22.99)	Station #12F. Note massive 4-m-high head coral, which forms part of an *in situ* barrier-reef framework. Note overlying *in situ* patch reef composed of a branching coral similar to *Acropora cervicornis* (staghorn coral). Most of the original aragonite has been leached away, creating molds of the original reef structure. Continue northward along road.
0.50 (0.80)	14.87 (23.79)	Station #13. Approximately 24 m above MSL, small exposure on west side of road at north end of Hess access road represents low-energy, inshore reef behind main reef exposure. See Appendix 3 for description. Proceed 0.10 mi to top of hill at beginning of dirt access road. Turn west (left) on Evans Highway and drive past stop lights at Martin Marietta at 0.35 mi, past Station #9 at another 1.80 mi, to junction with Airport Highway (additional 1.80 mi).
3.95 (6.32)	18.82 (30.11)	Turn right (north) on Airport Highway and drive north.
1.20 (1.92)	20.02 (32.03)	Juncture with Centerline Road. Turn left (west) and head toward Frederiksted. Large scar in mountain to right is rock quarry exposing Cretaceous deep-sea turbidites and gabbro sills.
2.40 (3.84)	22.42 (35.87)	Turn right (north) at gas station and drive past school at 0.30 mi. Hills to left are Miocene limestone, to the right are Cretaceous rock. Steeply dipping turbidites exposed in roadcut on right at another 0.30 mi. Continue on road for additional 0.40 mi.
1.00 (1.60)	23.42 (37.47)	Bear left and continue 0.35 mi in westerly direction past juncture. Stop across from green, two-story house on right.

Mileage	Cumulative Mileage	
0.35 (0.56)	23.77 (38.03)	Station #14. Approximately 18 m above MSL, exposure of soft, white, highly porous, chalky, pelletal mudstone on left (south) of road is riddled with wasp burrows and lacks fossil remains. Environment of deposition inshore of rocks exposed at Station #15.
		Continue southwest on same road to stop sign an 0.10 mi.
0.10 (0.16)	23.77 (38.19)	Turn left (south) at Frederiksted Community Mental Health Center, go one block, turn right (west) and stop beneath large tamarind tree on north side of road adjacent to post office.
0.06 (0.10)	23.93 (38.29)	Station #15. Approximately 18 m above MSL, two small outcrops (less than 1 m above road) of pelletal grainstone on south side of road contain *Acropora cervicornis* (?) molds and endolithic algae-coated pellets, no other organic debris. Color white beneath gray weathered surface. Well cemented, porous, interbedded.

End Road Log.

APPENDIX 2

Evans Highway (Station 9): sample number, thickness of individual stratigraphic beds, primary limestone rock type (according to Dunham, 1962) of each layer, principal organic components, and pertinent comments regarding each sample. Samples described in downsection order. Thickness of each bed measured vertically upslope (55°) from base of exposure (total 17.4 m). Calculated actual vertical thickness of section is 14.3 m. Color refers to that of fresh surfaces. Species identification code: poor = <10 sp., moderate = 10–19 sp., good = 20 or more sp.

Sample No.	Stratum Thickness (in)	Stratum Thickness (m)	Limestone Rock Type	Organic Components	Comments
9S	293	7.4	Mudstone	Benthic & pelagic Foraminifers	White; chalky; Foraminifera rare, very poorly preserved; no identification.
9R	74	1.9	Wackestone-packstone	Shell hash, benthic & pelagic Foraminifera, worm tube molds, micromolluscs (*Caecum*), coral debris, bivalve fragments	White; well cemented, thinly laminated channel deposit; microspar "grains;" very small globigerinids infilled with chalky matrix and coated with sparry calcite, yet are extremely fragile; most "Foraminifera" actually molds of tests; moderate identification.
9Q	59	1.5	Grainstone	Benthic & pelagic Foraminifera, coral fragments	Light gray to cream; very fine-grained, hard; chalky in unrecrystallized portions; not many coral fragments; fossils very poorly preserved; poor identification.
9P	31	0.8	Grainstone	Globigerinid "sand"	Red to orange; very hard; Fe-stained channel fill with high clay content (thin sectioned).
9O	5	0.1	Mudstone	Benthic & pelagic Foraminifera	Beige to gray; chalky; very poor preservation; Foraminifera not abundant, no identification.
9N	10	0.3	Grainstone	Shell hash, coral debris, benthic & pelagic Foraminifera	Yellow-gold to brown; very hard, Foraminifera not abundant, poorly preserved; poor identification.
9M	18	0.5	Packstone	Benthic & pelagic Foraminifera, echinoid spines, ostracod valves, arthropod claws, microgastropods, *Ehrenbergina*, *Pyrgo*, *Laticarinina* sp.	Light tan to gray; oxidized; chalky where unrecrystallized; leached porosity; abundant Foraminifera, benthics include monoserial and triserial arenaceous forms; moderate identification.
9L	25	0.6	Mudstone	Ostracods, mollusc fragments, benthic & pelagic Foraminifera, classic *Globorotalia menardii*	Beige to off-white; quartz grains; biotite; chalky globigerinid limestone washes easily but tests not clean; good preservation and identification.
9K	8	0.2	Grainstone	Echinoid spines, worm tubes, coral debris, mollusc fragments, benthic & pelagic Foraminifera, bryozoa, ostracods, micromolluscs (*Caecum*)	Yellow; highly recrystallized pelagic limestone; high secondary porosity; Foraminifera well preserved but most coated; moderate identification.
9J	39	1.0	Grainstone	Benthic & pelagic Foraminifera	Beige to light grey; chalky in unrecrystallized portions; high porosity; Foraminifera poorly preserved and fragmented; moderate identification.
9I	7	0.2	Mudstone	Shell hash, benthic & pelagic Foraminifera, echinoid spines, mollusc fragments, ostracod valves, bryozoa, arthropod claws, sponge spicules	Yellow-brown; highly recrystallized channel fill with quartz grains, abundant benthic sp., some pelagics; very poorly preserved, moderate identification.
9H	11	0.3	Grainstone	Pelagic Foraminifera	Beige to light gray; chalky in unrecrystallized portions; microspar "grains;" globigerinids matrix-coated; moderate identification.
9G	3	0.1	Grainstone	Shell hash, coral debris, benthic & pelagic Foraminifera	Yellow-brown and white; coarse-grained channel fill; very hard, recrystallized; 95% fossils too fragmented or coated to identify; poor identification.
9F	10	0.3	Grainstone	Benthic & pelagic Foraminifera, worm tubes, coral debris, *Ehrenbergina*, classic large, delicate *Globorotalia menardii*	Light gray to beige; chalky; good preservation, abundant foraminifera; moderate identification.
9E	21	0.5	Grainstone	Benthic & pelagic Foraminifera, echinoid spines, shell hash, coral fragments	Light gray; hard; fewer huge (>500μm) benthics than 9D; fairly good preservation; primarily benthics; moderate identification.
9D	7	0.2	Grainstone	Benthic & pelagic Foraminifera, echinoid spines, shell hash, coral fragments	Brown to tan; coarse-grained, hard, slightly graded; huge (>500 μm) benthics abundant; good preservation; moderate identification.
9C	4	0.1	Grainstone	Benthic & pelagic Foraminifera	Beige; coarse-grained, hard; abundant Foraminifera, tests well preserved; moderate identification.
9B	3	0.1	Mudstone	Benthic & pelagic Foraminifera, echinoid spines, ostracod valves	Beige; fine-grained, clayey; globigerinids abundant, very fragile, few benthic sp.; good preservation and identification.
9A	58	1.5	Mudstone	Benthic & pelagic Foraminifera, coral debris, echinoderm & bivalve fragments, bryozoa, ostracod valves, *Ehrenbergina*	Cream; massive, partly recrystallized; quartz grains; pelagic Foraminifera well preserved but coated with chalk and sparry calcite; some infilled, some empty tests, thus high secondary porosity; good identification.

APPENDIX 3

Amerada Hess Refinery (Stations 12, 13): sample number, vertical height from base of exposure, significant organic components, and pertinent comments regarding each sample. Primary limestone rock type (according to Dunham, 1962) for all beds is clastic grainstone. Samples described from north to south, downdip in exposure. Station 13 is northernmost unit, adjacent to but separate from Station 12 exposure. Species identification code: poor = <10 sp., moderate = 10-19 sp.

Sample No.	Height from Base (ft) (m)	Organic Components	Comments
13	---- ----	Mollusc, echinoid spine fragments, benthic Foraminifera, sponge(?) spicules	Light tan; beds dip 5° at 180° SW; poorly cemented with abundant angular carbonate debris and benthic sp., no pelagic specimens; poor identification.
12A	5'4" 1.6	Coral fragments, worm tubes, benthic & pelagic Foraminifera, ostracod valves, mollusc casts, *Pyrgo*	White to cream; recrystallized, amorphous carbonate debris; secondary porosity from undefinable fossil solution; Foraminifera rare, very small, altered and fragmented; poor identification.
12B	6'6" 2.0	Gastropod & coral(?) molds, *Halimeda* plates	White; porous; poor identification.
12C	6'0" 1.8	Coral fragments, benthic & pelagic Foraminifera, gastropod molds, echinoid spines, coralline algae	White to cream; hard, well cemented coral rubble with chalk and sparry calcite coating; no permeability; Foraminifera rare and recrystallized; poor identification.
12D	5'4" 1.6	Algal debris, echinoid spines, coral & gastropod molds, benthic & pelagic Foraminifera	White; porous; more friable than 12C; coral rubble with chalk and sparry calcite coating; hard, well cemented; no permeability; Foraminifera rare and recrystallized; poor identification.
12E	above & between 12C 12D, no measurement	Benthic & pelagic Foraminifera, coral & gastropod molds, bryozoa, alcyonarian spicules, echinoid spines, ostracod valves	Yellow and white; collected from apparent laminated hardground lens 0.3 x 11.4 m in near-horizontal length; highly porous; recrystallized and eroded Foraminifera common, delicate miliolids; moderate identification.
12F	7'2" 2.2	Mammoth (about 4 m high) coral head, undefinable fossil molds, benthic & pelagic Foraminifera, bryozoa, worm tubes, echinoid spines, *Archaias*	White, yellow staining; amorphous, highly lithified in places, friable in others; recrystallized molds abundant; Foraminifera rare and large; thick miliolids; poor identification.
12G	3'8" 1.1	Undifferentiated carbonate debris, benthic & pelagic Foraminifera, coiled gastropods, alcyonarian spicules	White; chalky and friable in unrecrystallized portions; porous; Foraminifera rare; no identification.
12H	6'0" 1.8	Shell hash, molds of undefinable fossils, coral debris, molluscs(?), benthic & pelagic Foraminifera	White; channel deposit in wedge containing 4-5 younger, smaller channel beds of fine-grained debris; highly porous, recrystallized; Foraminifera rare; no identification.
12I	6'5" 2.0	Undefinable carbonate debris of unknown origin; gastropod & coral molds, benthic & pelagic Foraminifera	White; chalky in unrecrystallized portions; molds and Foraminifera rare; no identification.
12J	4'6" 1.4	Molds of nondescript fossils, benthic & pelagic Foraminifera, sponge(?) spicules, coral debris, ostracods, micromolluscs (*Caecum*)	White; upper contact of sampled bed dips 3°40'; highly porous, amorphous, friable; eroded and recrystallized fossils; poor identification.
12K	5'9" 1.8	Coral & micromollusc molds, *Acropora cervicornis*	White; southernmost bed in exposure; massive, highly porous; molds well developed; Foraminifers rare and recrystallized; no identification.
12L	1.5-1.8 m between 12E & 12F	Reefal debris, shell hash, benthic & pelagic Foraminifera, sponge(?) spicules	Cream to white; hard, little chalk; eroded fossil fragments; benthic specimens slightly > pelagics; poor identification.

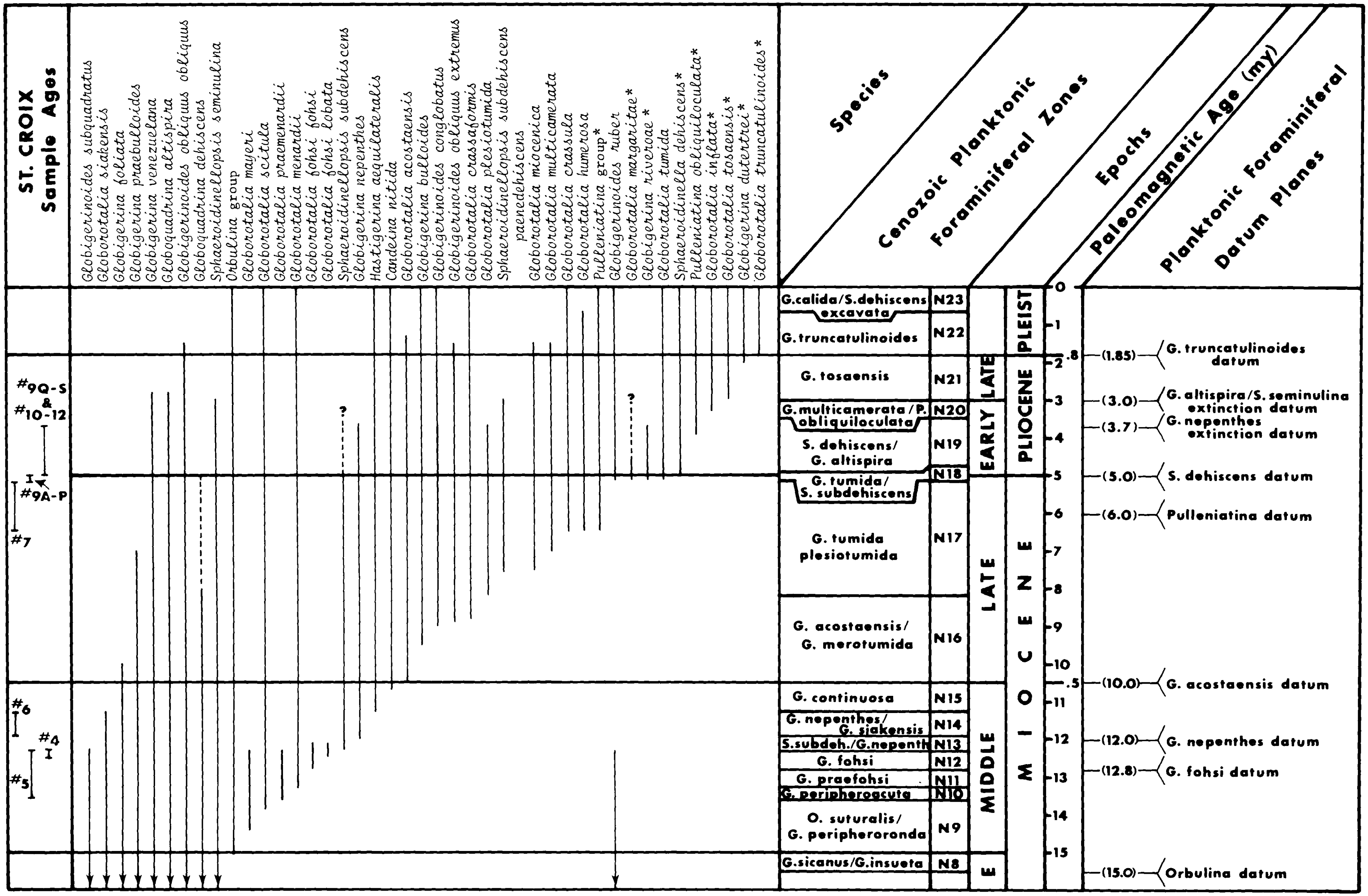


Figure 2. Chart showing ranges of 42 stratigraphically significant Miocene, Pliocene, and Pleistocene planktonic species and subspecies, the foraminiferal zones, and Cenozoic and paleomagnetic age. Species asterisked not identified from St. Croix but listed because of stratigraphic and/or paleoenvironmental importance. Note that *Globigerinoides ruber* disappears in the Caribbean at the top of Zone N12 and makes its reappearance in the late Miocene. Data on first and last occurrence (range) of species from Stainforth and others (1975) and Vincent (1977). Relationship between foraminiferal zones (Banner and Blow, 1965), epoch, and paleomagnetic time scale according to Berggren and van Couvering (1974). Species datum planes from Berggren (1973). Age assignments shown by vertical bars and identifying station number. Vertical bars indicate stratigraphic error within foraminiferal zones.

14
page 16 follows

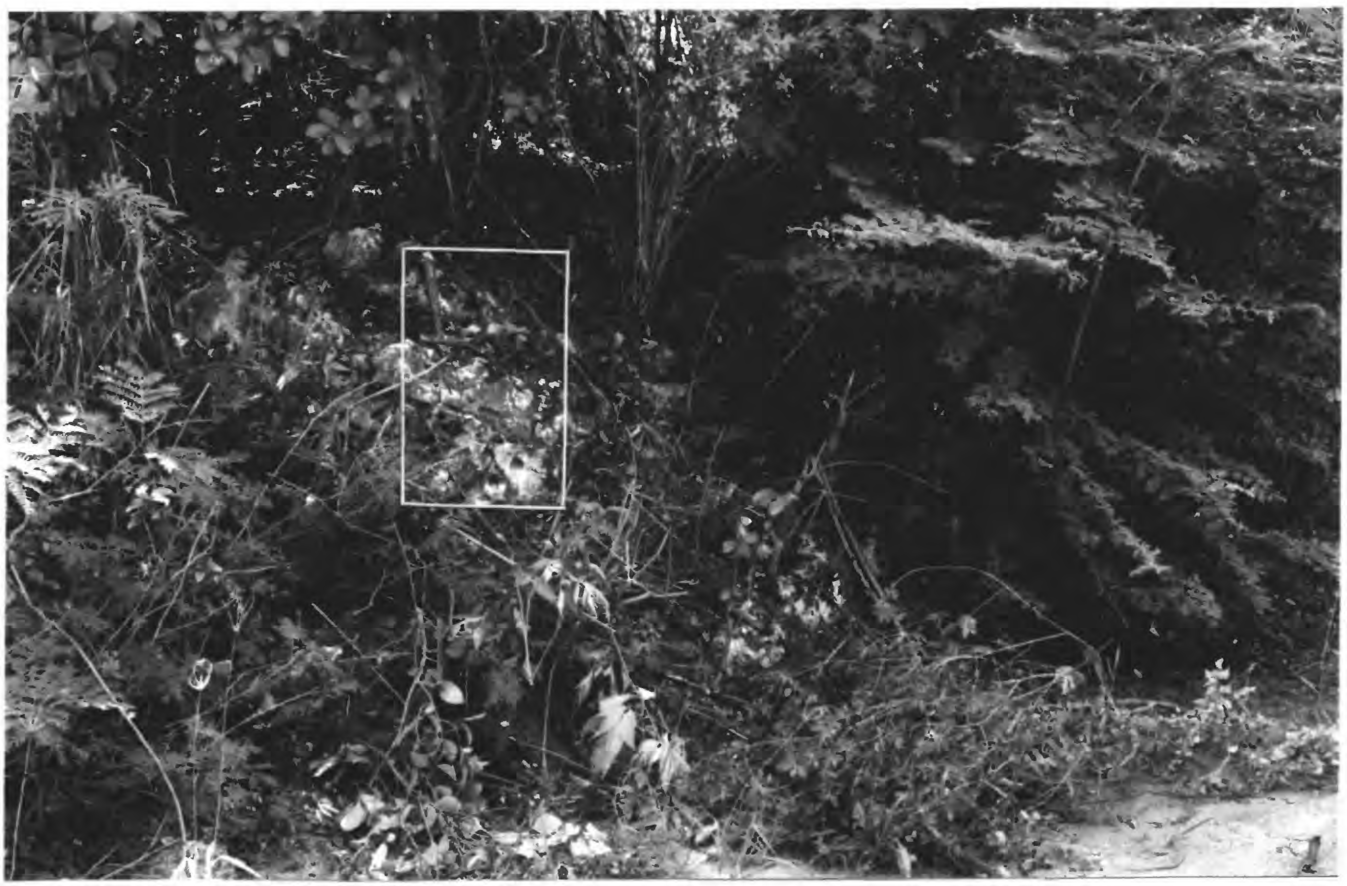


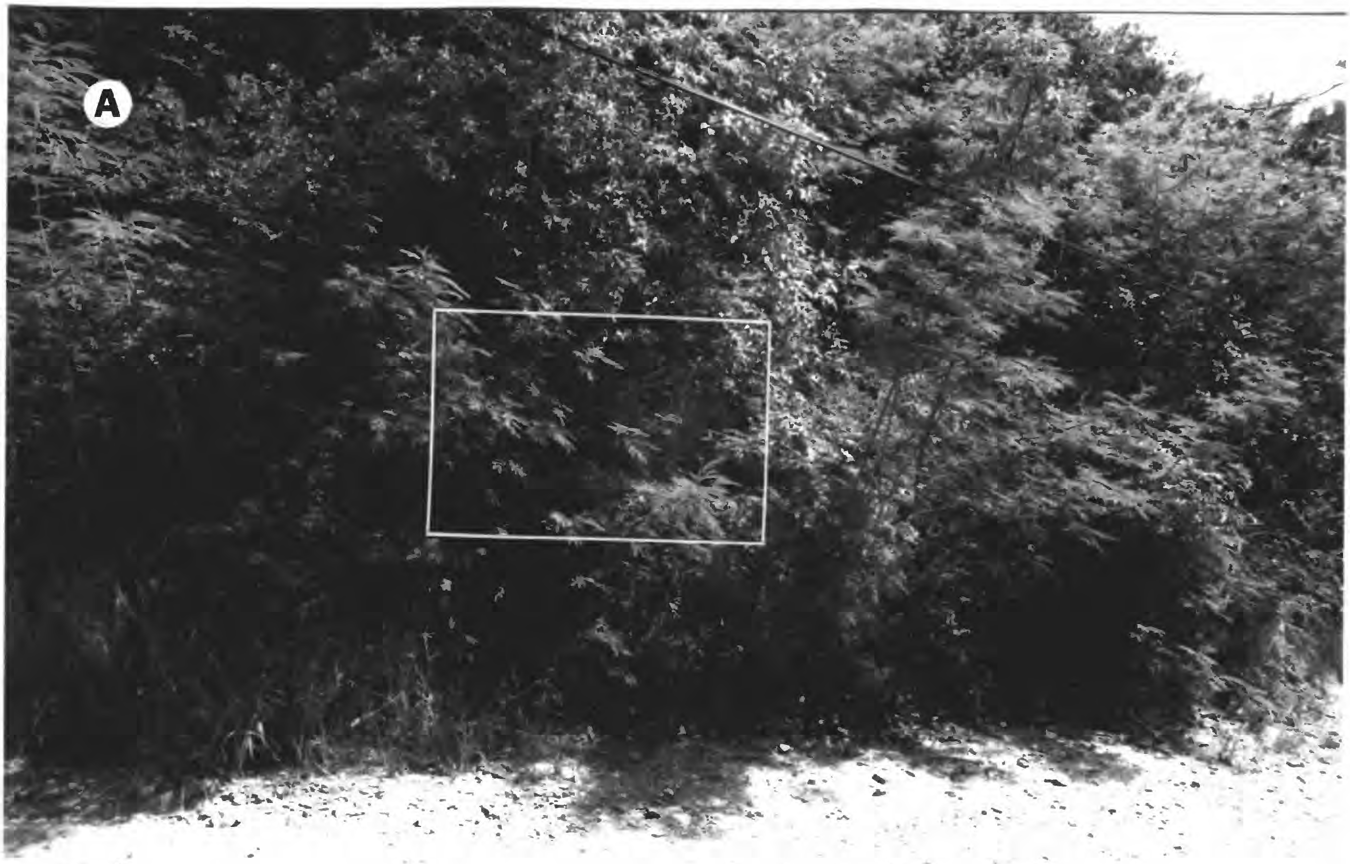
Figure 3. Station #1. Photograph taken on road to Salt River estuary, showing outcrop of lowest exposure of Miocene sediments (molluscan packstone) which overlie older (Oligocene?) volcanics exposed in roadbed. Sample collected from lower right corner of inset. Note rock hammer for scale. Photograph taken in 1981.

Figure 4. Station #2. (A) Photograph showing central high in residential turnabout composed of molluscan packstone. Note juncture at vehicle with main unpaved road to Salt River estuary. Inset, (B), shows area sampled. Note deep solution holes and molds of large, intact molluscs in the highly cemented, fine-grained rock. Photographs taken in 1981.


A


B

Figure 5. Station #3. (A) Photograph showing location of oxidized molluscan packstone approximately 1.3 km south of Salt River estuary. Inset, (B), indicates outcrop. Note abundant molds of molluscs, gastropods, and coral debris and lack of solution pitting in the friable, coarse-grained sediment. Photographs taken in 1981.


A


B

Figure 6. Station #4. (A) Photograph showing unconsolidated pelagic foraminiferal grainstone deposits alternating with thin hardbeds, representing distal turbidites of pelagic origin. Inset, (B), shows closeup of "Hill House" collection site, within first friable layer (behind machete handle) beneath massive, undifferentiated bed. Photographs taken in 1981.


A


B

Figure 7. Station #5. (A) Photograph showing location and very dense overgrowth of roadside outcrop area (arrow). Note juncture at vehicle of unpaved road, approximately 20 m south of collection site and opposite "New House" cut (Station #6). (B) Closeup of concealed outcrop of highly cemented, lithoclastic wackestone-packstone containing interbedded turbidites. Photographs taken in 1981.

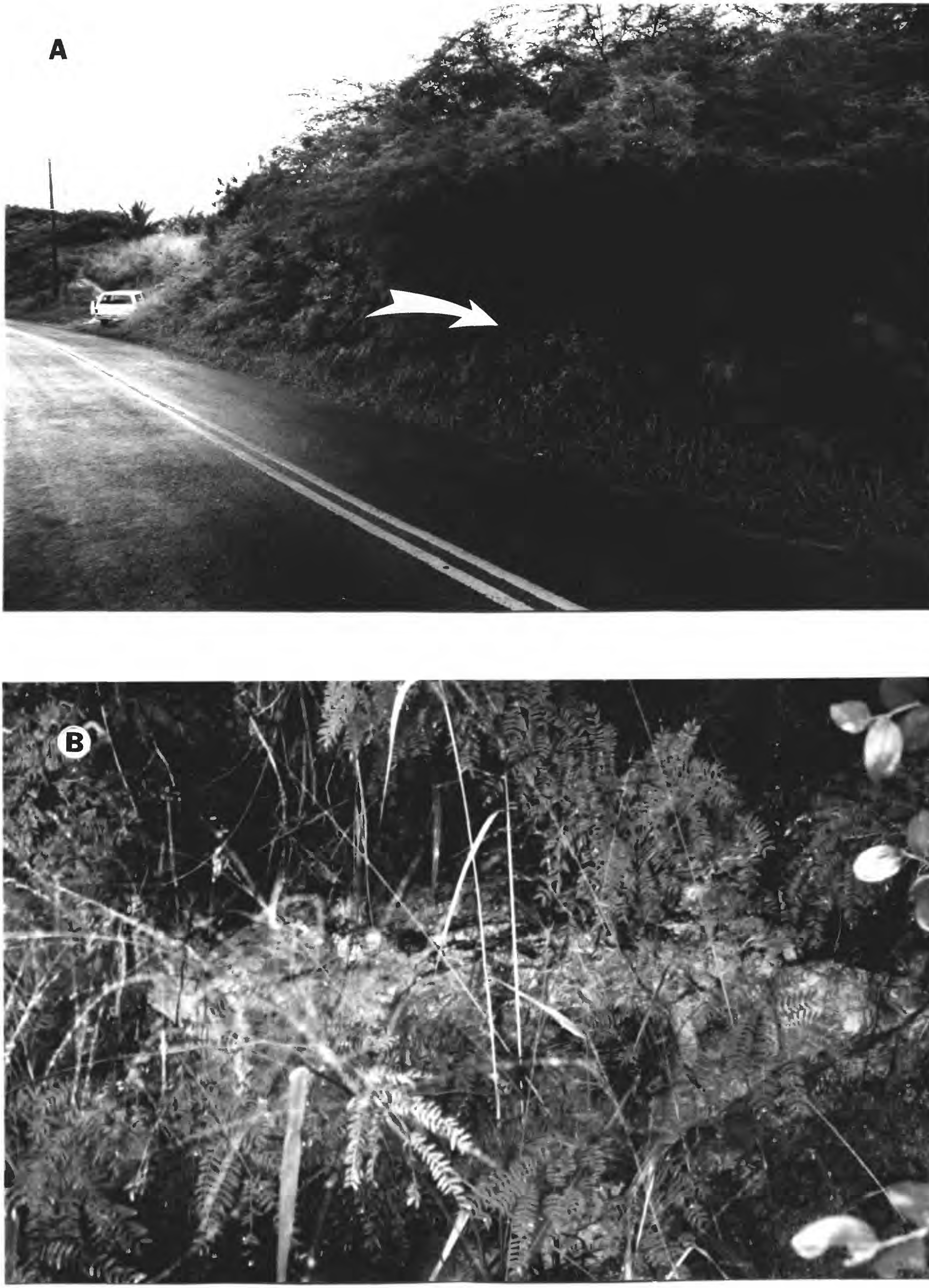
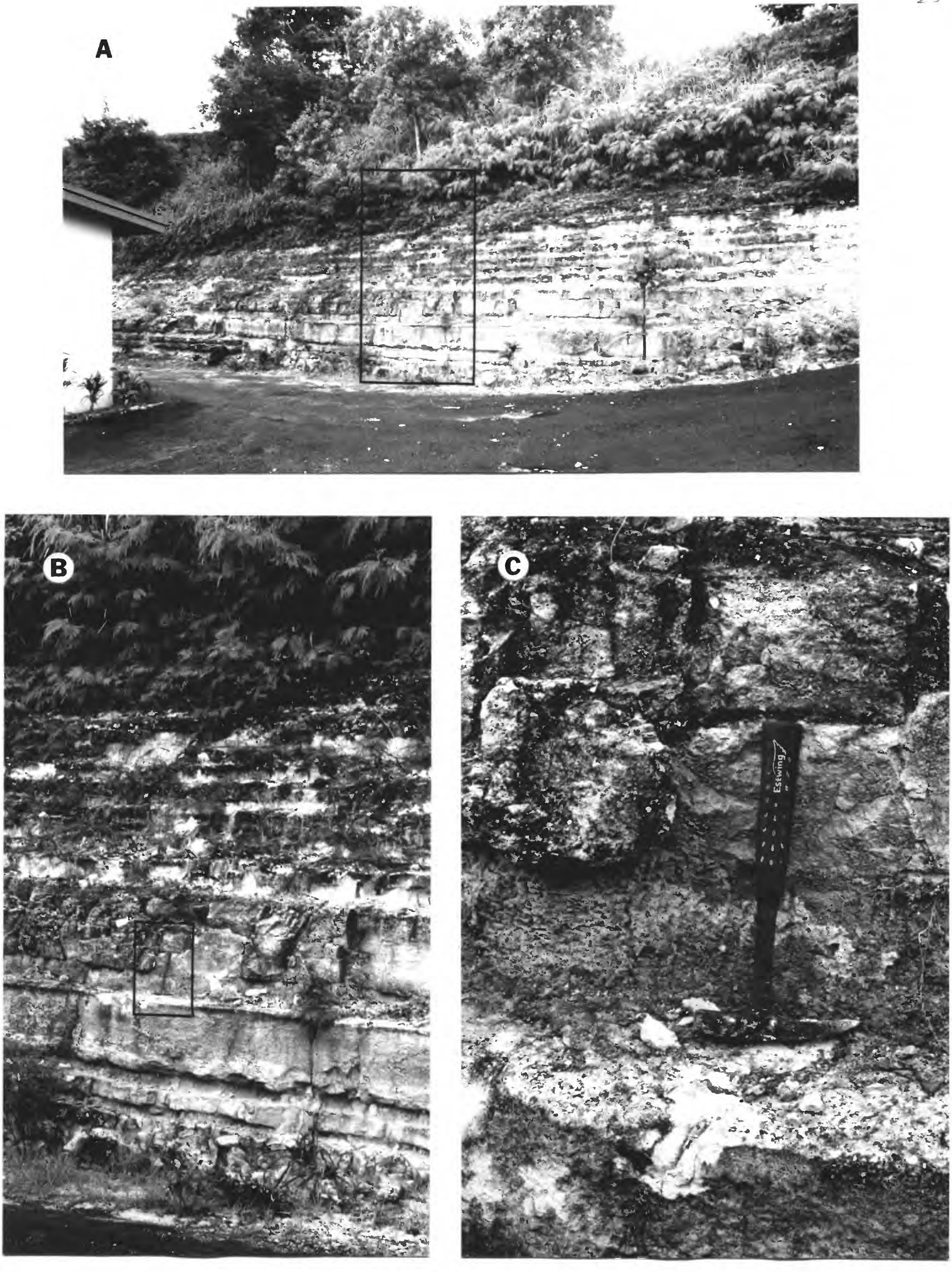

A
B

Figure 8. Station #6. (A) Photograph showing exposure of bioclastic grainstone along private driveway ("New House" cut), below and opposite juncture shown in figure 7A. Inset, (B), shows closeup of interbedded, proximal, deep-water fan terrigenous conglomerates and unconsolidated pelagic deposits. Inset, (C), shows sample area within uncemented, negative-relief layer (base of hammer). Photographs taken in 1981.


A
B
C
Estwing

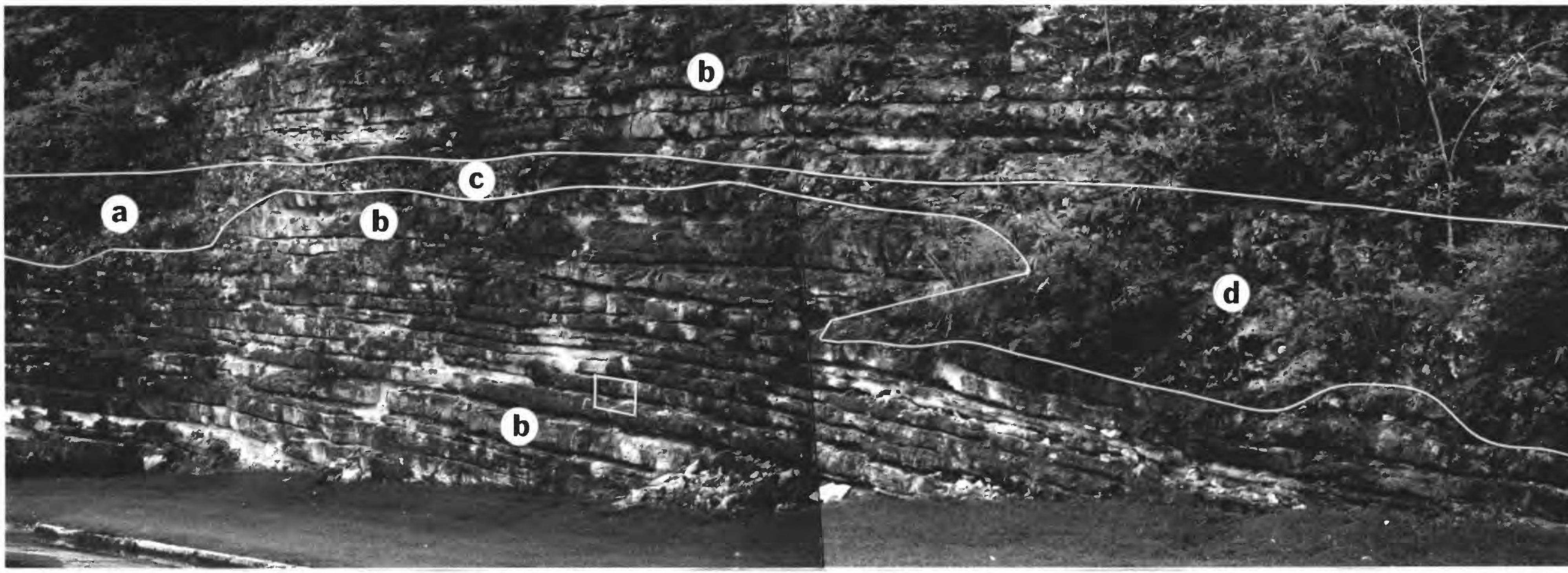
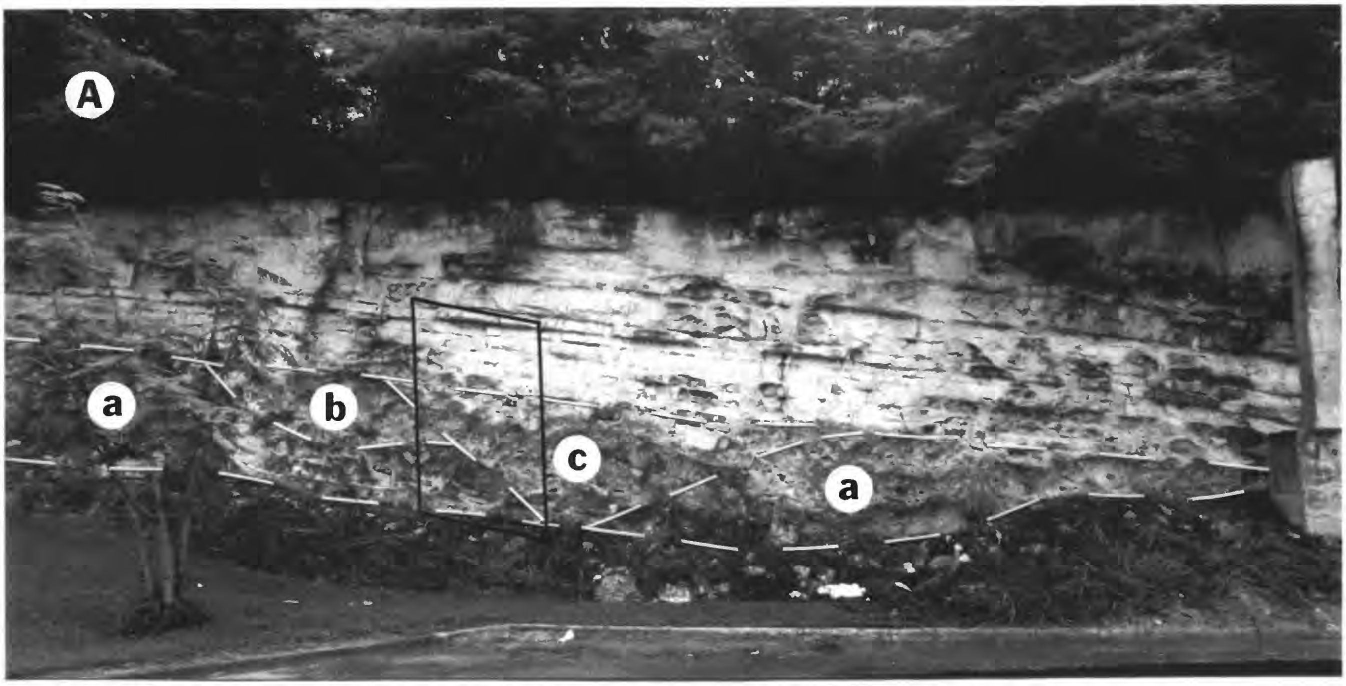


Figure 9. Station #7. Photomosaic of south end of Kingshill Limestone type section at Ville la Reine, showing channeled sedimentation (a) crosscutting thin, rhythmically bedded, fine-grained ash-fall (presumably volcanic) and detrital layers with negative relief and resistant, planktonic Foraminifera-rich chalk beds (b). Note debris flow deposit (c), possibly representing bank spillover turbidite, and thick lens of shallow-water and terrigenous rubble (d), indicating mass downslope displacement. Sample collected from unconsolidated recessed polymictic layer within inset, which contains rock hammer for scale. Photographs taken in 1981.

Figure 10. Station #7. (A) Photograph of north end of Kingshill Limestone type section at Ville la Reine, showing three deep-sea fan cut-and-fill episodes (a-c) in slump-filled channel structures overlain by horizontal beds of Miocene pelagic origin (positive relief) interbedded with over-channel turbidites (negative relief). Inset, (B), shows leached shallow-water reefoid and pebble (Cretaceous?) debris within channel deposits. Dark color is due to iron staining. Note secondary porosity from solution of small head coral at finger tip. Photographs taken in 1981.


A
a
b
c
a


B

Figure 11. Station #8. (A) Photograph showing dark, 18-cm-thick, planktonic Foraminifera-rich turbidite bed sandwiched between massive, lighter colored pelagic deposits at Fredensborg quarry. (B) Photograph of distal end of pelagic turbidite layer approximately 30 m southwest of area shown in figure 11A. Photographs taken in 1978.


A


B

Figure 12. Station #9. (A) Photomosaic showing exposure of pelagic deposits along Evans Highway near Manning. Note major unconformity and channel bed scouring (black line) separating lower Pliocene channel deposits from underlying late Miocene pelagic beds. Inset indicates area shown in figure 13B. Arrow indicates location of vertical sample site, approximately 25.5 m west of "Signal Ahead" sign (to left in photo) and 33 m east of "Crossroads" sign. (B) Closeup of sample site showing unconformity (dashed line) and beds sampled (A-S). Photographs taken in 1981.


LOWER PLIOCENE
UPPER MIOCENE

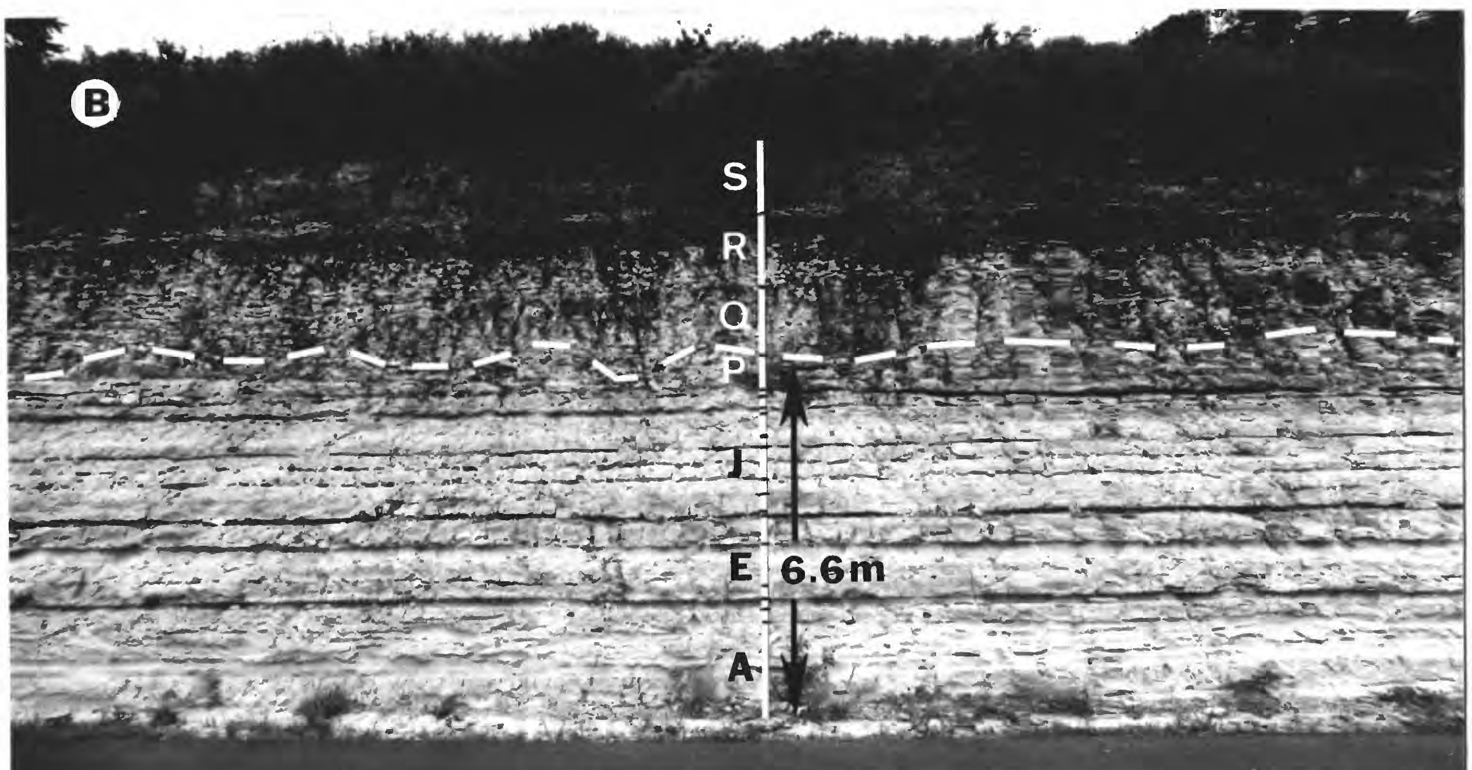
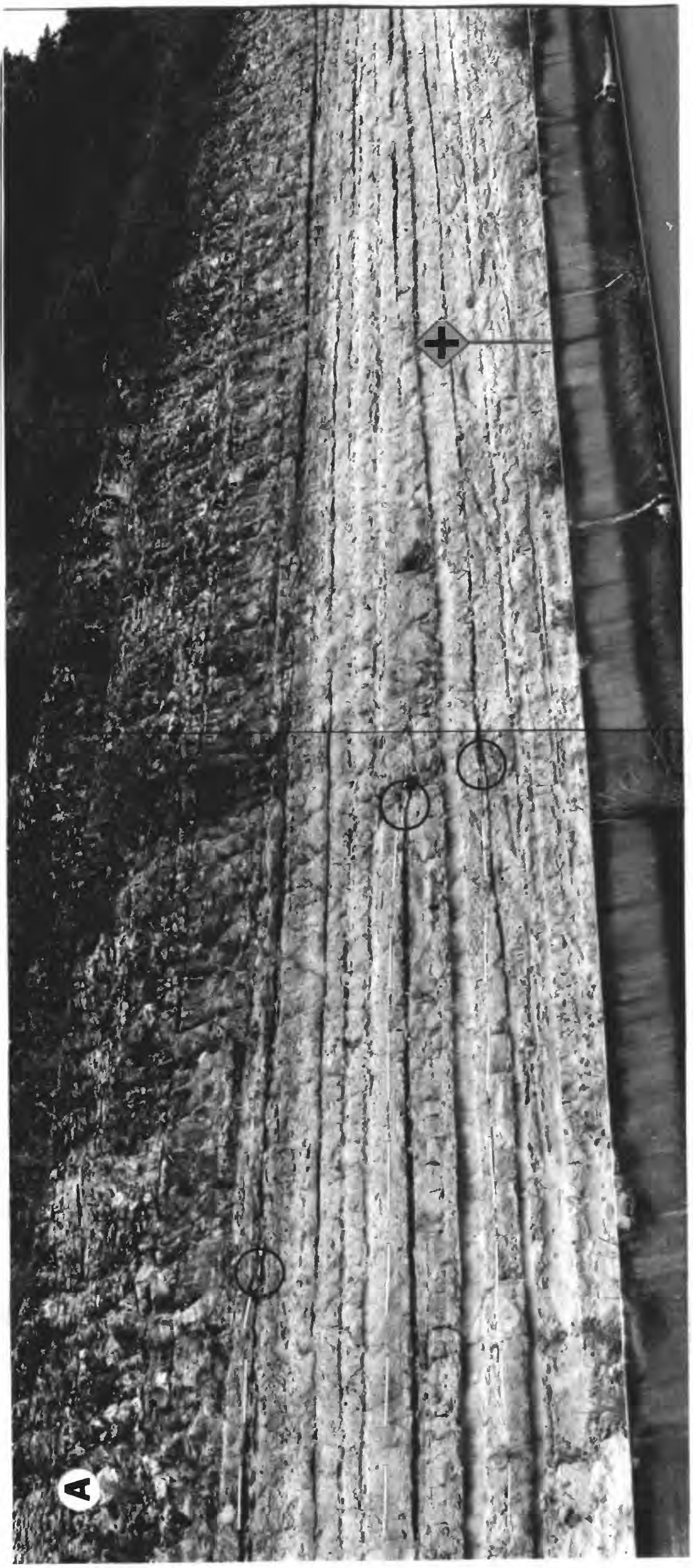

B
S
R
Q
P
J
E
A
6.6m

Figure 13. Station #9. (A) Closeup of western portion of Evans Highway exposure shown in figure 12A. Note pinchouts (circles) of distal channel deposits (dashed lines), which flowed from the northeast onto the deep-sea fan sediments. (B) Closeup of eastern portion of Evans Highway exposure shown by inset in figure 12A. Note extensive bioturbation (circles) and 7.5-cm-long worm tube (arrow). Photographs taken in 1981.


A


B

A

Figure 14. Photomosaics showing massive, highly cemented, amorphous hardgrounds of bioclastic mudstone exposed near Airport Road at Stations #10 (A) and #11 (B). Insets indicate sample sites. Area within white inset on (A) is shown in figure 15. Photographs taken in 1981.

B

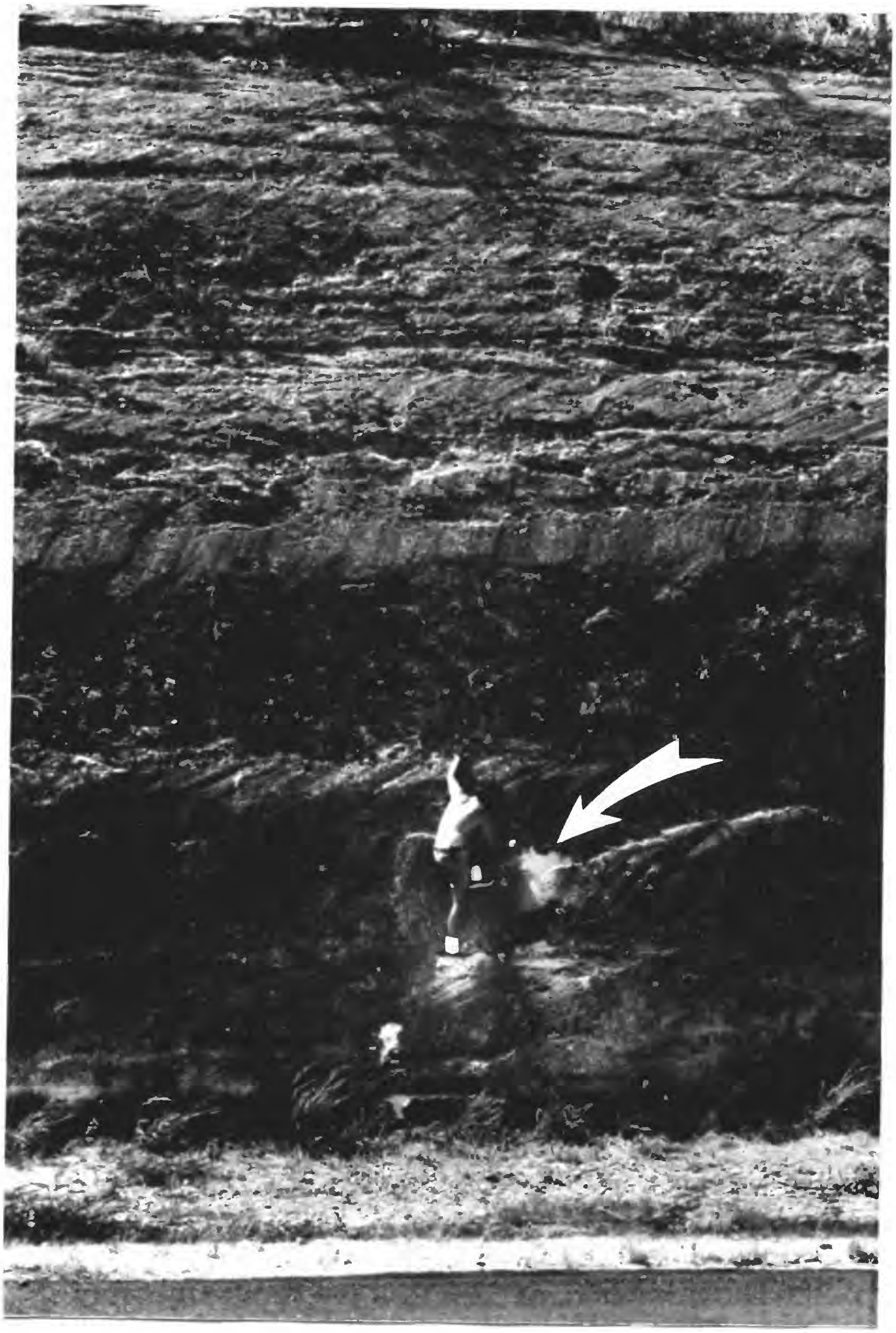
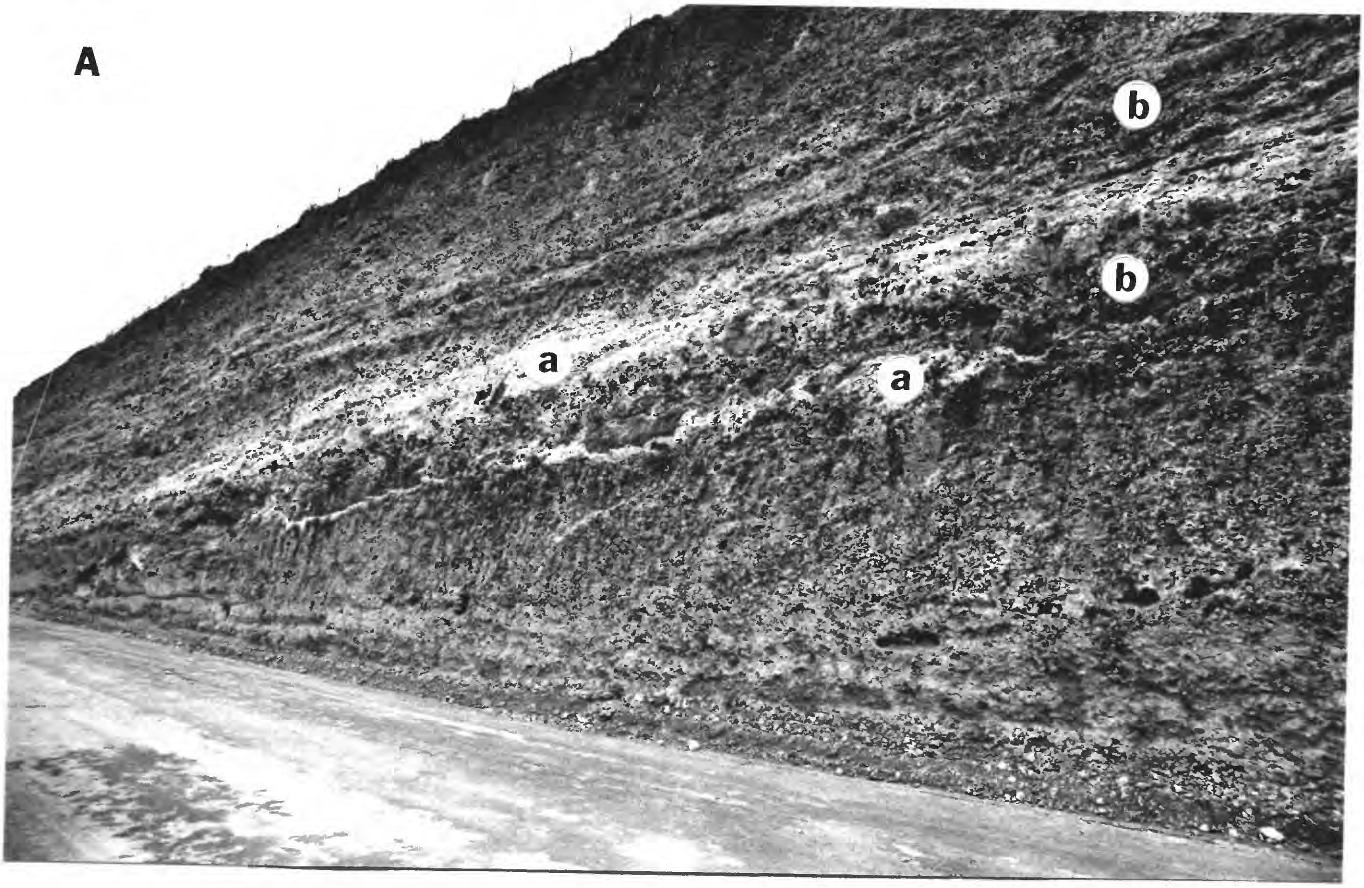


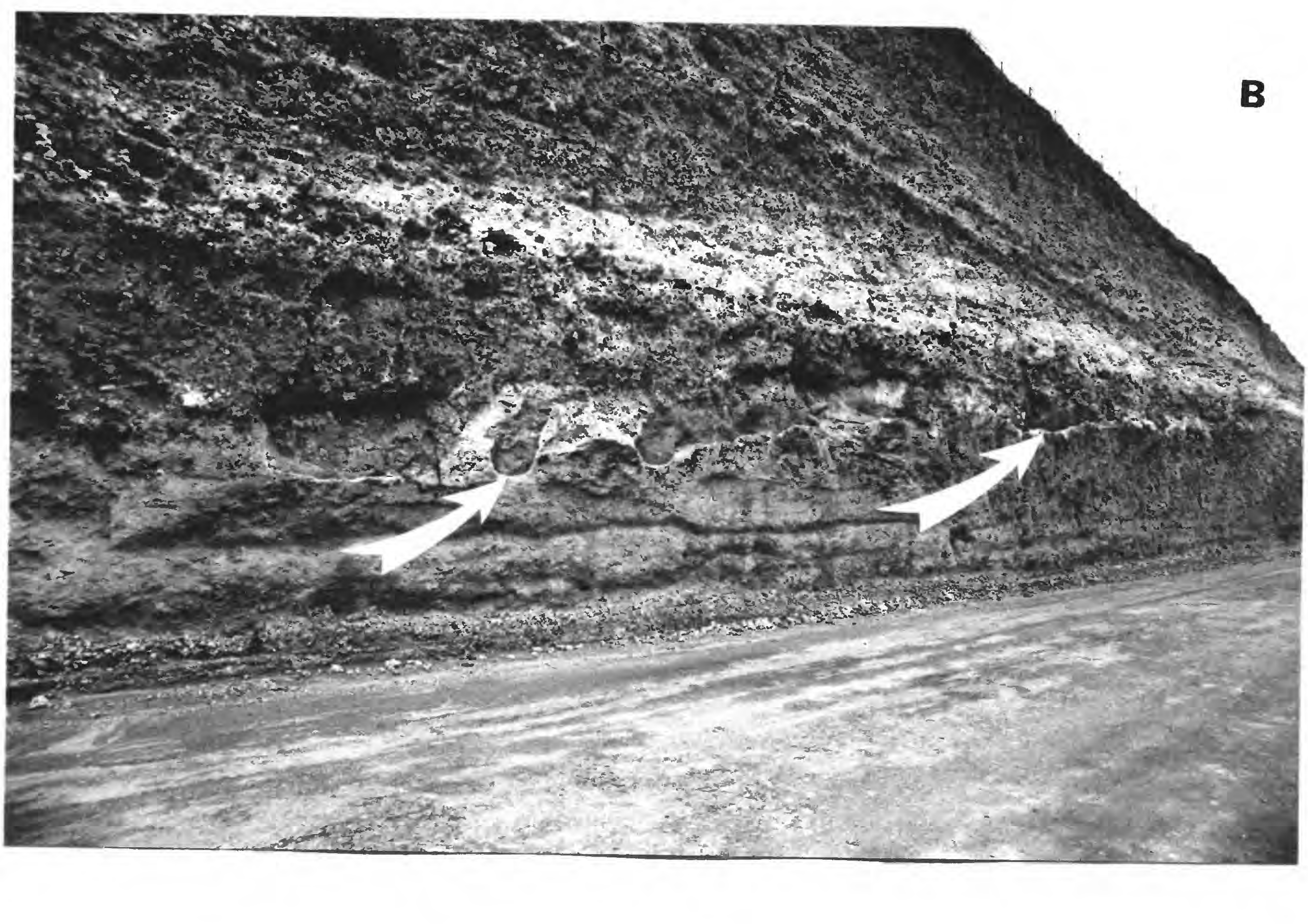
Figure 15. Station #10. Closeup of sample area indicated by inset on figure 14A. Note fresh white mudstone beneath weathered surface (arrow). Photograph taken in 1978.

Figure 16. Station #12. (A) Photograph looking southwest near south end of Hess roadcut. Lighter colored material (a), representing ancient sea floors, alternates with darker colored debris flow deposits (b). (B) Photograph showing view of same area looking northwest. Note karst pits and soilstone crust layer about 3 m above roadbed (arrows). Photographs taken in 1981.

A



B



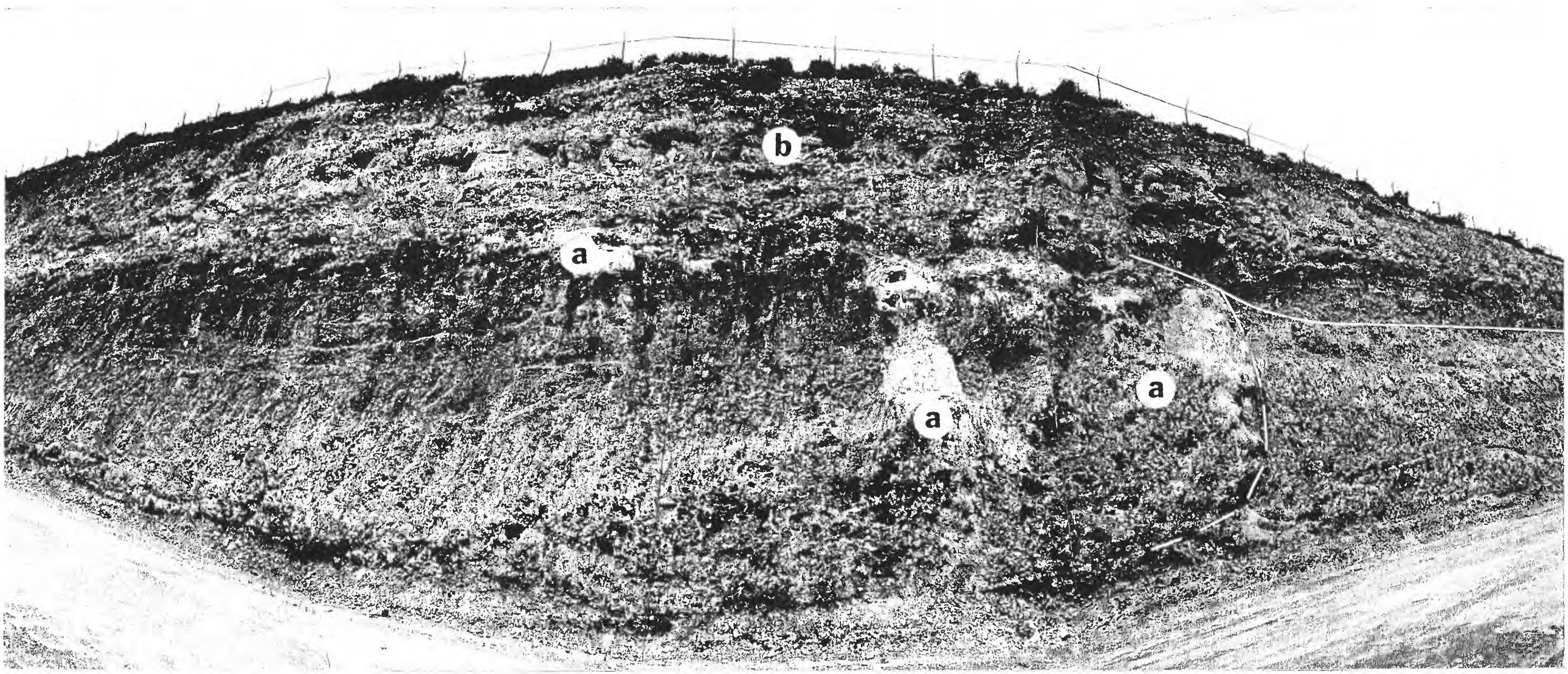
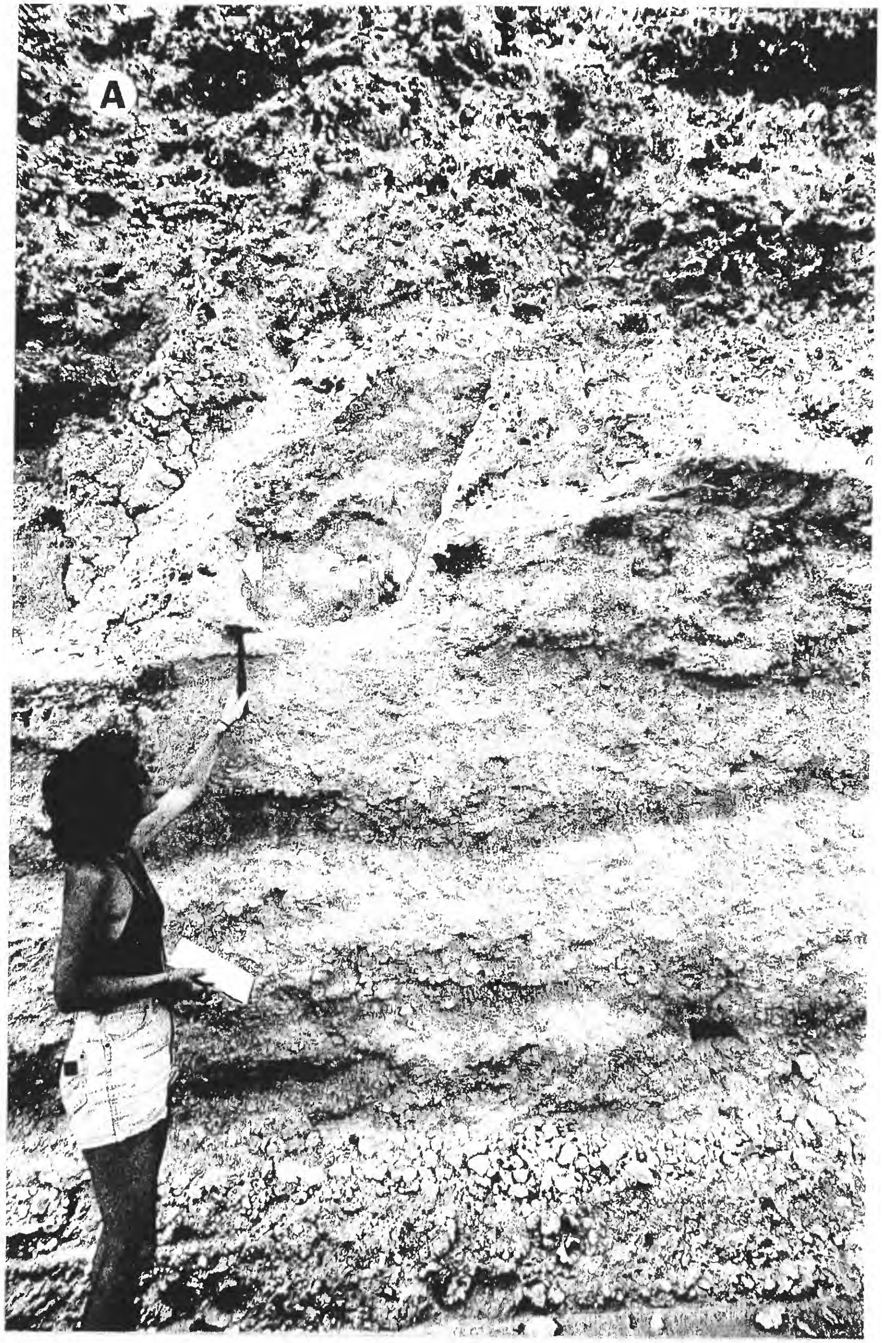


Figure 17. Station #12F. Photomosaic showing *in situ* main barrier-reef framework at Hess cut. Main reef is composed of massive head corals (a), which are overlain by an *in situ* patch reef (b), composed primarily of a leached branching coral similar to *Acropora cervicornis* (staghorn coral). Dashed white line delineates 4-m-high head coral. Photographs taken in 1981.

Figure 18. Station #12. Photographs showing closeup views of (A) karst pit and soilstone crust seen in figure 16B and (B) leached, highly cemented nature of limestone exhibited throughout the Hess exposure. Note moldic structure of large head coral beneath and above pen. Photographs taken in 1981.


A

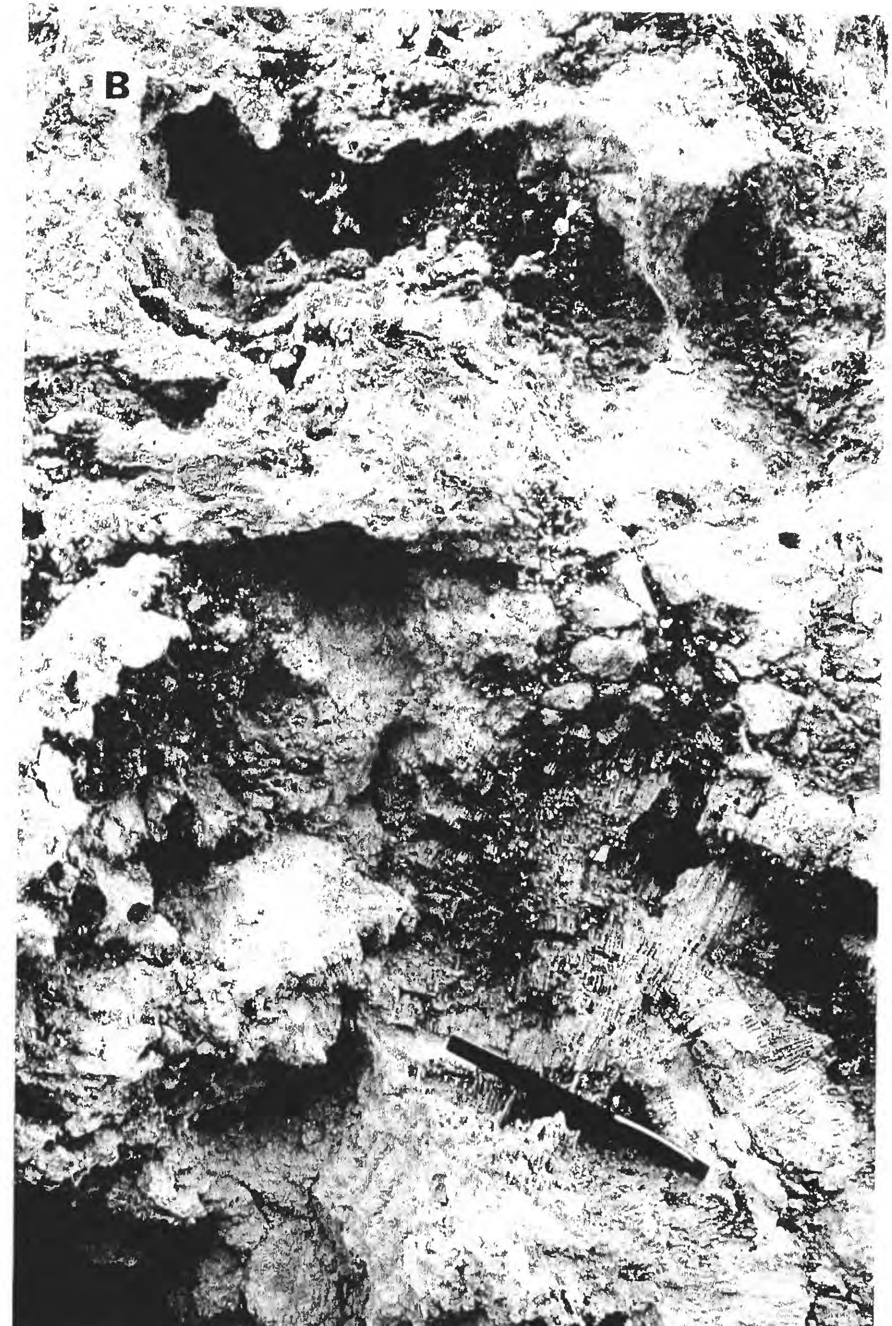
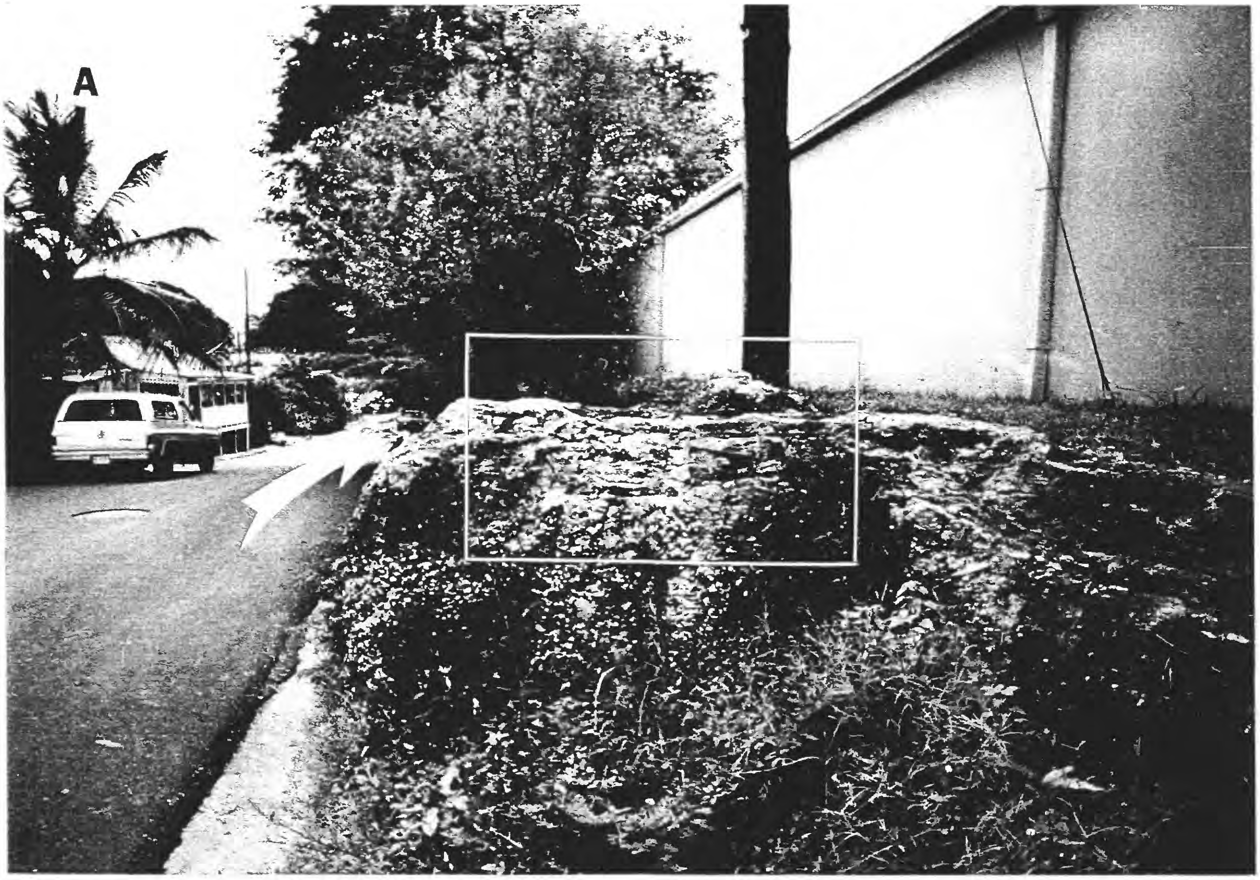

B

Figure 19. Station #13. Photograph showing sample site (inset) at inshore-reef exposure at north end of Hess cut. Note main barrier-reef exposure (Station #12) to the south at extreme left. Photograph taken in 1981.

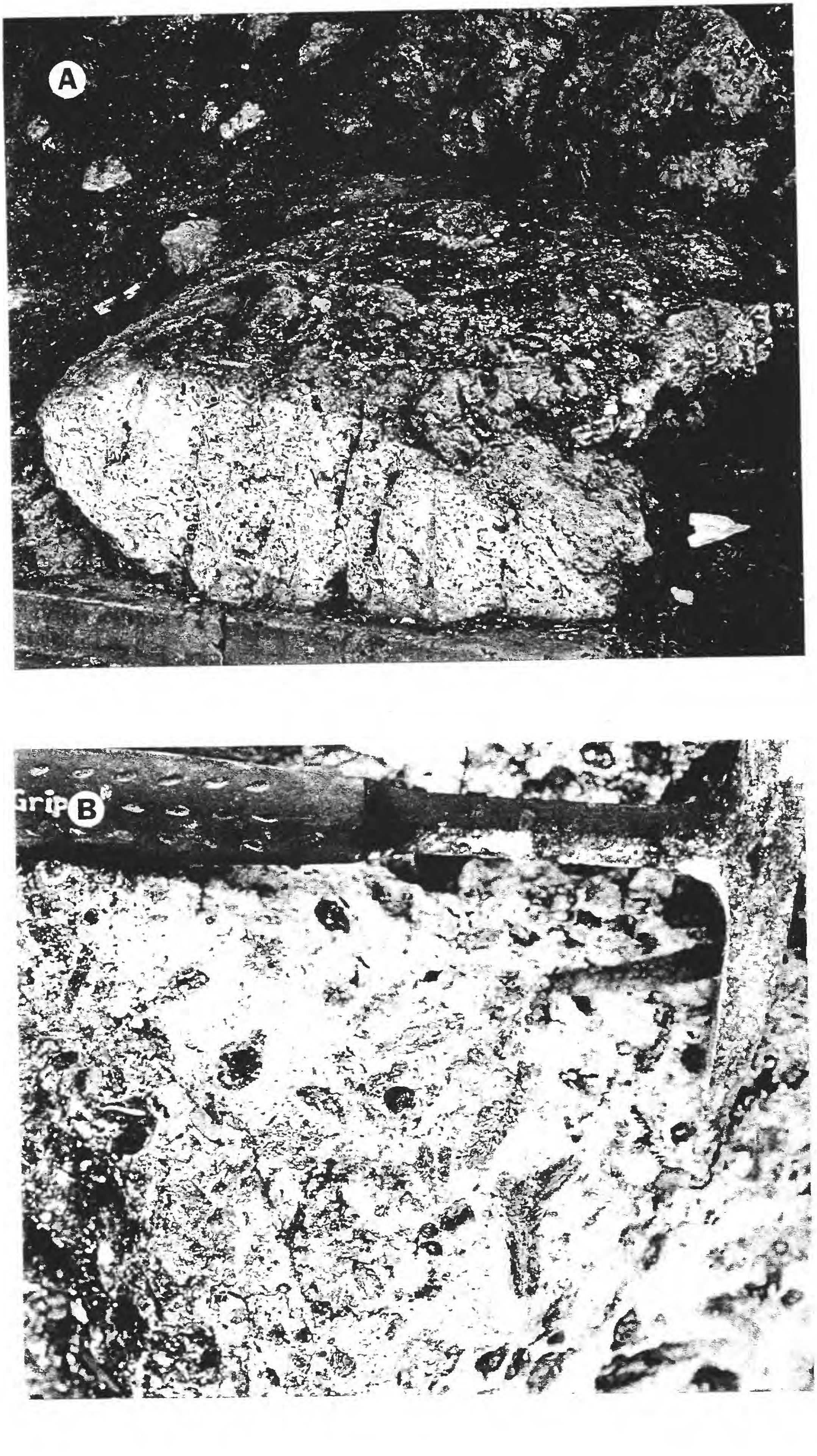
Figure 20. Station #14. Photograph showing soft, porous, pelletal mudstone exposed along road at eastern perimeter of Frederiksted. Inset indicates area sampled. Photograph taken in 1981.

Figure 21. Station #15. (A) Photograph showing outcrop of cemented pelletal grainstone at Frederiksted. Arrow indicates location of adjacent moldic *Acropora cervicornis* (?)-pelletal grainstone shown in figures 22A and 22B. Inset, (B), shows closeup of portion sampled (base of hammer). Photographs taken in 1981.


A


B

Figure 22. Station #15. (A) Photograph showing curbside pelletal grainstone containing moldic *Acropora cervicornis*(?). Note rock hammer for scale. (B) Closeup of moldic *Acropora cervicornis*(?)-reef structure. This shallow-water reef appears to be in place and lay offshore from the pelletal grainstone deposit shown in figure 20 (Station #14). Photographs taken in 1981.


A
Grip
B

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