PALEONTOLOGICAL RESEARCH INSTITUTION FOUNDED 1932

Bulletins of American Paleontology

VOLUME 92, NUMBER 327 APRIL 24, 1987

The Fauna and Paleoecology of the Late Pleistocene Marine Sediments of Southeastern Virginia

by

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BULLETINS OF AMERICAN PALEONTOLOGY

and

PALAEONTOGRAPHICA AMERICANA

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Subscriptions to *Bulletins of American Paleontology* may be started at any time, by volume or year. Current price is US $30.00 per volume. Numbers of *Palaeontographica Americana* are priced individually, and are invoiced separately on request.

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Table 1 — Distribution of the Late Pleistocene fauna of southeastern Virginia by sample locality and stratigraphic unit, showing occurrence, relative abundance, and zoogeographic distribution for each species A = abundant, C = common, R = rare, S = some, X = reported. - = no occurrence See p 6 for definitions of these terms

ACREDALE																				POWELLS CROSSROADS					RECENT				FORMATION
Great Bridge			Norfolk Lower		Norfolk Upper										Kempsville Lower		Kempsville Upper			London-bridge	Sand Bridge Lower		Sand Bridge Upper		Caribbean Carolinian	S. Virginian	N Virginian	Boreal	Member
17f	18e	22c	17e	20b	17d	18d	21a	22b	25a	26a	27	28	29	30	17c	22a	17a	17b	23	18c	18b	20a	18a	19a					Sample Number
																													FORAMINIFERA
S	-	-	S	S	R	S	S	S	S	-	-	-	-	-	R	S	-	-	-	-	R	-	S	-	-	-	-	-	Ammonia limbatobeccarii
R	-	-	R	S	R	-	-	S	S	-	-	-	-	-	-	-	-	-	-	S	S	R	S	-	X	X	X	-	Ammonia sobrina
R	R	-	R	-	R	-	R	S	S	-	-	-	-	-	-	S	-	-	-	-	S	R	-	-	X	X	X	-	Ammonia tepida
-	-	-	-	-	R	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Bolivina sp
-	-	-	-	R	R	S	S	R	R	-	-	-	-	-	S	R	-	-	-	-	R	-	-	-	-	-	-	-	Buccella depressa
-	-	-	-	-	-	-	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	C	-	X	X	X	Buccella frigida
-	-	-	-	R	R	R	-	R	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	X	X	X	X	Buliminella cf. B. elegantissima
-	-	-	-	R	-	-	S	-	R	-	-	-	-	-	S	S	-	-	-	-	-	S	-	R	X	X	X	X	Cibicides lobatulus
C	R	-	R	C	C	C	S	C	C	-	-	-	-	-	C	R	-	-	-	-	C	S	C	-	X	X	X	-	Elphidium articulatum
R	R	-	S	-	R	S	C	R	S	-	-	-	-	-	C	S	-	-	-	-	S	-	S	-	-	X	X	-	Elphidium brooklynense
C	C	-	C	C	C	C	C	C	C	-	-	-	-	-	C	C	-	-	-	-	C	C	C	-	X	X	X	X	Elphidium clavatum
R	-	-	S	S	C	R	-	S	R	-	-	-	-	-	R	R	-	-	-	-	S	R	-	-	X	X	X	-	Elphidium discoidale
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	-	-	-	-	-	R	R	-	X	X	X	X	Elphidium excavatum
S	S	-	C	S	S	S	R	S	R	-	-	-	-	-	S	C	-	-	-	-	C	C	S	-	X	X	X	-	Elphidium galvestonense
R	S	-	R	S	S	S	-	S	R	-	-	-	-	-	S	R	-	-	-	-	S	-	-	-	X	X	X	-	Elphidium gunteri
S	-	-	S	-	-	-	S	R	S	-	-	-	-	-	C	C	-	-	-	-	-	-	-	-	X	X	X	X	Elphidium incertum
-	-	-	-	S	S	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	R	R	-	-	X	X	-	-	Elphidium cf. E poeyanum
-	-	-	-	-	-	S	S	-	-	-	-	-	-	-	C	S	-	-	-	-	-	S	S	R	X	X	X	X	Elphidium subarticum
S	R	-	S	S	S	S	R	S	-	-	-	-	-	-	R	R	-	-	-	-	C	R	S	-	X	-	-	-	Elphidium tumidum
-	R	-	-	R	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	Globigerina sp.
-	-	-	R	R	R	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Globulina sp.
-	-	-	S	R	S	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	R	X	X	X	-	Hanzawaia concentrica
R	-	-	R	S	S	S	-	S	-	-	-	-	-	-	R	S	-	-	-	-	S	-	S	-	X	X	X	X	Haynesina germanica
-	-	-	R	R	R	R	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Lagena sp.
-	-	-	-	-	R	R	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Massilina sp.
-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	- -	Nonion sp.
R	-	-	S	S	S	S	S	S	S	-	-	-	-	-	-	S	-	-	-	-	S	R	R	-	X	X	X	-	Nonionella atlantica
-	-	-	-	-	R	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Nonionella sp
-	S	-	-	S	S	-	-	R	-	-	-	-	-	-	-	R	-	-	-	-	S	R	-	-	X	X	X	-	Poroeponides lateralis
-	R	-	-	-	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	X	X	X	-	Poroeponides cf. P. repanda
R	-	-	S	S	R	R	R	R	-	-	-	-	-	-	R	S	-	-	-	-	-	R	-	-	-	X	X	-	Protelphidium tisburyense
-	-	-	-	-	-	-	S	R	S	-	-	-	-	-	S	S	-	-	-	-	R	R	R	-	-	X	X	X	Pseudopolymorphina cf. P. novangliae
R	-	-	-	-	C	S	-	R	R	-	-	-	-	-	R	R	-	-	-	-	R	-	-	-	X	X	-	-	Quinqueloculina compta
S	-	-	R	-	C	-	R	R	-	-	-	-	-	-	S	S	-	-	-	-	-	S	-	R	X	X	X	-	Quinqueloculina jugosa
S	-	-	S	-	C	C	-	S	S	-	-	-	-	-	R	R	-	-	-	-	S	-	-	-	X	X	-	-	Quinqueloculina lamarckiana
-	-	-	-	-	-	S	-	R	S	-	-	-	-	-	S	S	-	-	-	-	-	-	-	-	-	-	-	-	Quinqueloculina microcosta
R	-	-	R	-	S	R	-	R	R	-	-	-	-	-	S	S	-	-	-	-	-	-	-	-	X	X	-	-	Quinqueloculina poeyana
S	-	-	S	-	C	C	S	S	C	-	-	-	-	-	C	C	-	-	-	-	-	-	S	-	X	X	X	X	Quinqueloculina seminula
-	-	-	-	S	-	S	-	S	S	-	-	-	-	-	S	S	-	-	-	-	S	R	-	-	X	X	X	X	Rosalina columbiensis
-	-	-	-	S	S	S	R	S	S	-	-	-	-	-	S	S	-	-	-	-	S	R	S	-	X	X	X	-	Rosalina floridana
-	-	-	-	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Textularia sp.
R	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	Tiphotrocha cf. T. comprimata
																													PORIFERA
-	-	-	-	C	C	-	-	-	-	-	-	-	-	-	C	-	-	-	-	-	-	-	-	S	X	X	X	-	Cliona sp.
-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	indeterminant spicules
																													COELENTERATA
-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	X	X	X	-	Astrangia danae
																													BRYOZOA
-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	X	X	X	X	Cribrilina punctata
-	-	-	-	S	R	-	-	R	S	-	-	-	-	-	S	C	-	S	-	-	S	S	-	-	X	X	X	X	Cryptosula pallasiana
-	-	-	R	-	R	S	-	S	-	-	-	-	-	-	-	-	-	-	-	S	-	R	-	S	X	X	-	-	Cupuladria biporosa
-	-	-	R	-	R	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	Cupuladria owenii
-	R	-	R	-	R	C	R	C	-	-	-	-	-	-	-	-	-	-	-	S	S	S	-	C	X	-	-	-	Discoporella umbellata depressa
S	S	S	R	C	S	-	-	C	C	-	-	-	-	-	C	C	-	-	-	-	-	R	-	R	X	X	X	-	Electra monostachys
-	-	-	-	S	R	S	-	S	-	-	-	-	-	-	R	-	-	-	-	-	S	-	-	-	X	-	-	-	Hippoporidra calcarea
-	-	-	R	R	R	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	Hippoporina porosa
-	-	-	-	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	-	Hippoporina cf. H. verrilli
S	S	S	S	C	C	C	S	C	C	-	-	-	-	-	C	C	-	-	-	-	S	C	-	-	X	X	X	-	Membranipora tenuis
-	-	-	-	R	S	S	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	X	X	-	-	Membraniporella cf. M petasus
R	-	-	R	S	S	-	-	S	-	-	-	-	-	-	S	R	-	-	-	-	-	-	-	-	X	X	X	X	Microporella ciliata
-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	-	Parasmittina nitida
R	-	R	C	C	C	S	R	C	C	-	-	-	-	-	C	C	-	C	-	-	C	C	R	S	X	X	X	-	Schizoporella errata
-	-	-	-	C	S	C	-	C	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	Stephanosella cornuta
																													ANNELIDA
-	-	-	S	-	C	C	-	-	C	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	X	X	X	-	Hydroides dianthus
-	-	-	S	S	C	C	-	-	S	-	-	-	-	-	C	-	-	-	-	-	-	-	-	C	X	X	X	-	Polydora sp.
																													MOLLUSCA BIVALVIA
S	C	-	-	-	-	C	S	-	-	C	X	-	-	-	S	-	-	-	-	-	S	-	-	-	X	X	X	-	Abra aequalis
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	R	-	X	X	-	Aligena elevata
C	C	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	-	Anadara ovalis
-	-	-	-	R	A	C	A	C	-	C	X	X	X	-	A	S	-	S	-	-	C	C	C	C	X	X	X	-	Anadara transversa
-	-	-	-	-	S	C	-	C	-	-	-	-	-	-	S	C	-	S	-	-	C	S	A	-	X	X	X	-	Anomia simplex
-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	S	-	-	S	-	-	C	-	C	-	X	X	-	-	Argopecten gibbus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	A	-	-	-	-	-	-	X	X	X	Astarte castanea
-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	S	-	-	R	-	-	-	-	-	-	X	X	X	-	Barnea truncata
S	-	-	S	-	C	S	-	S	-	C	-	-	-	-	C	S	-	S	-	-	S	S	-	S	X	-	-	-	Bornia longipes
-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	Codakia costata
A	A	-	S	S	A	A	C	C	-	C	-	X	-	-	C	C	-	S	-	-	A	A	C	S	X	X	X	-	Corbula contracta
R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	-	Corbula swiftiana
-	C	-	-	-	S	C	S	-	-	S	-	-	-	-	C	R	-	S	-	-	C	C	C	S	X	X	X	-	Crassinella lunulata
C	S	A	C	-	S	S	-	C	-	S	X	X	-	-	C	S	-	C	-	C	S	S	C	S	X	X	X	X	Crassostrea virginica
-	-	-	-	S	A	R	-	A	A	C	-	-	-	-	A	R	-	-	-	-	-	R	-	-	X	X	X	X	Cumingia tellinoides
-	-	-	-	-	-	-	S	-	-	-	X	-	-	-	-	-	-	R	R	-	-	-	-	-	-	X	X	X	Cyclocardia borealis
-	S	-	S	A	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	-	Cyrtopleura costata
-	-	-	C	-	-	C	A	-	-	S	-	-	-	-	S	S	-	S	-	-	C	-	S	S	X	X	-	-	Dinocardium robustum
-	C	-	-	S	-	C	S	-	-	C	-	-	-	-	S	-	-	-	-	-	C	-	-	C	X	-	-	-	Diplodonta punctata
-	-	-	-	-	C	C	A	-	-	S	-	-	-	-	S	-	-	S	-	-	C	-	-	S	X	X	X	-	Divalinga quadrisulcata
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	X	-	-	-	Donax parvula
-	-	-	-	-	-	S	-	-	-	C	-	-	-	-	S	-	-	-	-	-	S	-	-	A	X	X	X	-	Donax roemeri protracta
-	C	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	Dosinia discus
-	C	-	-	-	A	A	A	C	C	C	X	-	-	-	A	C	-	A	-	C	A	S	A	S	X	X	X	X	Ensis directus
-	-	-	-	S	-	S	-	-	-	C	-	-	-	-	S	-	-	-	-	-	S	-	-	-	X	X	-	-	Gemma purpurea
-	-	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	Geukensia demissa
-	-	-	-	-	R	R	S	-	-	R	X	-	-	-	-	-	-	-	-	-	R	-	-	-	X	X	X	-	Ischadium recurvum
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	X	-	-	-	Linga amiantus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	X	X	X	X	Lyonsia hyalina
A	C	-	-	C	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	Macoma balthica
A	S	-	-	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	Macoma constricta
-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	X	-	-	-	Macrocallista nimbosa
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	X	-	-	-	Martesia cuneiformis
-	-	-	-	A	A	A	A	A	A	C	X	-	-	-	A	C	-	A	-	-	A	A	A	S	X	X	-	-	Mercenaria campechiensis
-	-	-	C	C	-	-	C	-	-	-	X	X	-	X	C	-	-	-	-	-	-	C	-	-	X	X	X	X	Mercenaria mercenaria
-	-	C	-	-	C	-	-	C	-	S	-	-	-	-	S	C	-	C	-	-	-	-	-	-	X	-	-	-	Modiolus squamosus
A	C	-	S	A	S	S	C	C	C	A	X	-	X	X	A	-	-	-	-	-	S	-	-	A	X	X	X	X	Mulinia lateralis
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	X	-	-	-	Musculus lateralis
S	S	S	-	S	-	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	X	X	X	Mya arenaria
-	-	S	-	-	-	C	-	S	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	S	X	X	X	X	Mysella planulata
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	C	-	-	-	-	-	-	-	-	-	X	X	X	Mytilus edulis
-	-	-	-	-	S	-	-	S	-	R	-	-	X	-	S	S	-	S	-	-	-	-	S	-	X	X	X	-	Nuetia (Eontia) ponderosa
-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	R	-	-	-	-	-	-	-	X	-	Nucula major
C	S	-	C	S	C	C	S	C	-	C	-	-	-	-	C	-	-	R	-	-	C	-	C	S	X	X	X	X	Nucula proxima
C	-	-	C	-	-	-	S	-	-	C	-	X	X	-	R	-	-	S	-	C	C	-	-	R	X	X	X	-	Nuculana acuta
-	-	-	-		R	A	R	-	-	S	-	-	-	-	S	C	-	S	-	-	C	-	-	-	-	X	X	X	Pandora gouldiana
-	-	-	-	-	C	C	R	S	-	C	-	-	-	-	S	-	-	-	-	-	C	-	-	A	X	X	-	-	Pandora trilineata
R	S	-	-	-	-	C	-	-	-	S	-	-	-	-	R	-	-	-	-	-	-	-	-	-	X	X	-	-	Paramya subovata
-	A	-	-	-	-	C	C	-	-	C	-	-	-	-	A	-	-	-	-	-	C	-	C	A	X	X	-	-	Parvilucina multilineata
-	-	-	-	-	-	C	R	-	-	S	-	-	-	-	S	R	-	-	-	-	C	-	-	S	-	X	X	X	Periploma leana
-	R	-	S	S	-	S	-	-	R	-	-	-	-	-	C	-	-	S	-	-	S	-	-	S	X	X	X	X	Petricola pholadiformis
-	C	-	S	-	S	A	-	-	R	-	-	X	-	-	-	-	-	-	-	A	A	-	-	-	-	X	X	X	Pitar morrhuana
-	-	-	-	-	-	A	S	-	-	A	-	-	-	-	C	-	-	-	-	-	-	A	C	S	X	X	-	-	Pleuromeris tridentata
S	S	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	Raeta plicatella
S	C	-	C	S	-	S	-	C	-	-	X	-	-	X	S	S	-	C	S	-	C	S	C	-	X	X	-	-	Rangia cuneata
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	X	-	-	-	Semele cf S. purpurascens
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	X	X	X	X	Solemya velum
-	-	-	-	-	-	A	-	-	C	C	X	-	-	-	A	A	S	A	-	-	A	S	A	S	X	X	X	X	Spisula solidissima
-	C	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	-	Tagelus divisus
C	C	-	A	A	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	-	Tagelus plebius
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	X	X	X	X	Tellina agilis
-	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	Tellina alternata
-	C	-	-	R	C	C	C	C	-	A	X	-	-	-	A	S	-	S	-	-	A	-	C	A	X	-	-	-	Tellina texana

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Bulletins of American Paleontology

VOLUME 92, NUMBER 327 APRIL 24, 1987

The Fauna and Paleoecology of the Late Pleistocene Marine Sediments of Southeastern Virginia

by

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1259 Trumansburg Road
Ithaca, New York, 14850 U.S.A.

Library of Congress Card Number: 87-60753

Printed in the United States of America
Allen Press, Inc.
Lawrence, KS 66044 U.S.A.

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THE FAUNA AND PALEOECOLOGY OF THE LATE PLEISTOCENE MARINE SEDIMENTS OF SOUTHEASTERN VIRGINIA

By

R. S. Spencer[1] and L. D. Campbell[2]

ABSTRACT

The late Pleistocene faunas of southeastern Virginia are essentially modern in character, with approximately 97 percent of the 332 species extant. The fossils are contained in two transgressive–regressive depositional cycles, assigned here to the Acredale and Powells Crossroads formations, two new stratigraphic units. One new species of gastropod, *Cingula norfolkensis*, is described.

Paleoecologic analyses of Acredale assemblages and sediments indicate a cyclic event beginning with estuarine conditions and comparatively cool temperatures during the deposition of the basal Great Bridge Member. More open bay or inlet conditions and warmer temperatures were established during deposition of the superjacent lower part of the Norfolk Member, giving way to a sublittoral shelf environment and warm water temperatures at peak transgression during deposition of the upper part of the Norfolk Member. Overlying faunas indicate shallowing for the lower part of the Kempsville Member with temperatures similar to those indicated for the upper portion of the Norfolk. The upper part of the Kempsville Member deposits are a complex of beach sands, channel fill, and very shallow sublittoral environments with drastically reduced temperatures.

The younger Powells Crossroads Formation, representing a second transgressive–regressive cycle, is less extensively developed, but two members can be recognized in the study area. Cool temperatures and estuarine conditions prevailed during deposition of the Londonbridge Member. Warm temperatures and sublittoral shelf environments prevailed during deposition of the lower portion of the Sand Bridge Member. Temperatures remained warm during deposition of the upper part of the Sand Bridge Member, while a lowering of sea level produced a complex of beach sands, washover fans, and channels dominated by intertidal species.

This pattern of sea level and inferred temperature variation for the Virginia late Pleistocene section is compatible with the oxygen isotope and sea surface temperature patterns from deep sea cores from isotope stage 5—70,000 to 125,000 years before the present.

INTRODUCTION

The first definitive work on Virginia's marine Pleistocene fauna was done by Woolman and Boyer (1898), who listed species found in spoil along the banks of the Dismal Swamp Canal and who correctly recognized the mixed Pliocene–Pleistocene character of that deposit. Subsequent work on the fauna was principally done by Clark and Miller (1912), Mansfield (1928), and H. G. Richards (summarized in 1962). Most of the interest and efforts of Virginia Pleistocene workers during the period 1900 to 1960 centered, not on the poorly-known faunas, but rather upon the delineation and interpretation of the various scarps and terraces (see Oaks and Coch, 1973, pp. 11–14 for an excellent summary).

In the early and middle 1960's, construction began on the Virginia Beach Expressway (Virginia Route 44) and Interstate Route 64, opening numerous sand pits in the lower Tidewater area for road bed material. The larger pits frequently penetrated fossiliferous Pleistocene sediments and a few attained maximum depths of 18 m. These pits offered a unique opportunity for the study in outcrop of Pleistocene faunas and sediments.

Before highway construction, a series of test cores were taken along the proposed routings of the new roads. These cores, supplemented by additional borings, provided Oaks and Coch with material for their dissertations and publications (Oaks and Coch, 1963, 1968, 1973; Oaks, 1965; Coch, 1965). These studies, which presented the first cohesive analysis of the southern Virginia Coastal Plain, were sedimentologic and geomorphic rather than paleontologic, but they did include brief listings of species based upon Horace Richards' identifications. The fauna was principally used to distinguish between Pleistocene and "Yorktown Miocene" assemblages.

Our stratigraphic conclusions differ from those of Oaks and Coch in the relative and absolute age assignments of certain stratigraphic units. We reject their application of the time–rock concept for determining formations, and consequently, relegate many of Oaks and Coch's formations to member status.

For a useful summary of Atlantic Coastal Plain stratigraphy and various concepts developed during the 1960's pertaining to formation recognition and correlation, the reader is referred to the numerous articles collected and edited by Oaks and DuBar (1974). Even with the comprehensive listing of 121 Pleistocene species from Wailes Bluff and Langleys Bluff, Maryland (Blake, 1953), progress on the paleontology of the area has lagged behind stratigraphic efforts. Richards (1966,

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1967) published two brief notes recording Oaks and Coch's new molluscan records. Meanwhile, large collections were obtained by the U. S. National Museum, by Gerald Johnson at the College of William and Mary, and by Randall Spencer at Old Dominion University. A most thorough collection of macrofossils was made by Paul Drez, then a student at Old Dominion University. The vertebrate portion of the Drez collection has been published (Ray *et al.,* 1968). Richards and Campbell (1972) published a brief report on some new Virginia Pleistocene molluscan occurrences. The Old Dominion, Drez, and Campbell collections provide the foundation of this report, supplemented by specimens from the U. S. National Museum provided through the courtesy of Dr. Thomas Waller.

Regional study of the micropaleontology began with Woolman and Boyer (1898) who listed diatom species. Whitehead (1972) reported the late Wisconsinan to early Holocene palynology of the Dismal Swamp peat. Valentine (1971) and Cronin (1979) discussed and interpreted the ostracode fauna of the upper part of the Norfolk Member.

From all sources we can document a fauna of 332 invertebrate and vertebrate species (Table 1). Valentine's (1971) ostracode samples were drawn from the upper part of the Norfolk Member and the lower part of the Kempsville Member only. With their deletion, 252 species, which were sought in every member and section, remain. Recent distributional records were found for 223 of these species (Table 1), providing the data base from which our paleoecologic and paleoclimatic reconstructions are drawn. Table 1 also contains distribution data of each species encountered in this study by stratigraphic unit as well as their relative abundance in each of the stratigraphic units. The terms used in determining the relative abundance of a species in an assemblage are as follows: Abundant (A) = greater than 5 percent occurrence of a species in a sample; Common (C) = between 1 and 5 percent occurrence of a species in a sample; Some (S) = less than 1 percent occurrence of a species in a sample; and Rare (R) = two to 10 specimens of a species found from all specimens collected.

ACKNOWLEDGMENTS

We are particularly indebted to Mr. Paul Drez who generously made his extensive collections and unpublished records available to us. Appreciation is extended to Donald Moore (University of Miami, Miami, FL) for his assistance in micromolluscan identification; to Allen Cheetham (U. S. National Museum of Natural History, Washington, DC) and Patricia L. Cook (British Museum, Natural History, London, England) who provided critical advice on the Bryozoa; to J. E. Hazel (Louisiana State University, Baton Rouge, LA), who provided critical advice in the systematic ordering of the ostracodes; and to Donald J. Colquhoun (University of South Carolina, Columbia, SC) for discussions pertaining to Pleistocene geomorphology and regional stratigraphy. Special thanks are extended to Allen Cheetham, Donald J. Colquhoun, R. Tucker Abbott, T. Cronin, L. Ward, and especially to Druid Wilson for their critical review of all or parts of the typescript. Later versions of the manuscript were reviewed by T. Cronin and L. Ward. Scanning electron micrographs of the microgastropods were taken through the courtesy of Dr. N. Watabe and staff at the Belle Baruch Laboratory, University of South Carolina, Columbia, SC.

Appreciation is also extended to Sarah Campbell, who aided in collecting and identification, helped type early versions of the manuscript; and to several paleontology classes at Old Dominion University, whose members helped in the initial collecting and sorting of the large quantity of material acquired during the early stages of this study.

The Old Dominion University Research Foundation provided funds to support a student assistant for summer fieldwork during the early stages of this work.

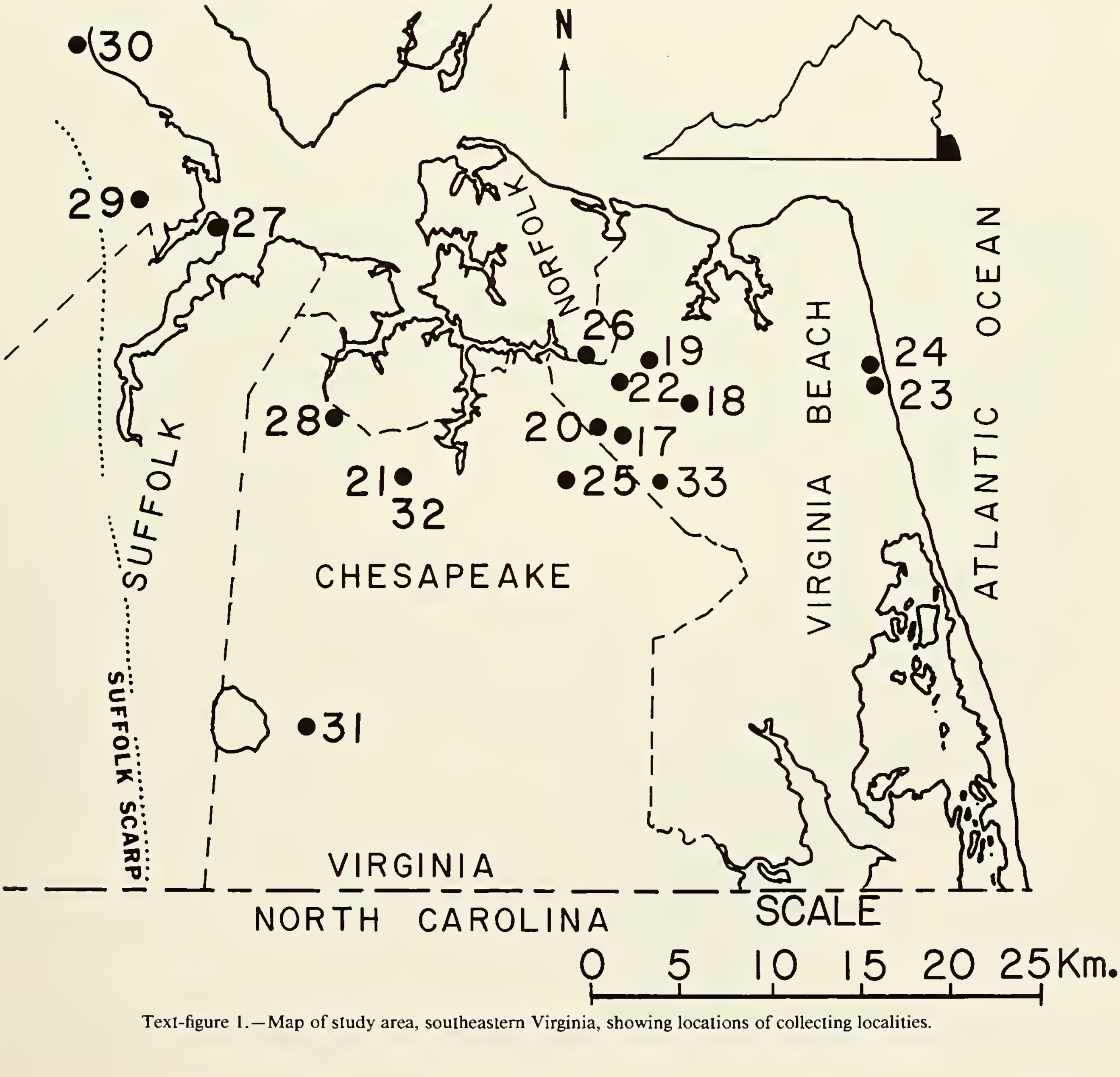
The College of Sciences, the Research Foundation, and the Department of Geological Sciences at Old Dominion University, helped to defray publication costs.

STRATIGRAPHIC FRAMEWORK

Pleistocene stratigraphy for the Coastal Plain of southeastern Virginia is very complex, involving rapid lateral and vertical changes of a wide variety of back barrier, barrier, marginal marine and marine shelf facies. Sometimes these lateral changes are so rapid, often occurring within a few meters vertically and less than 100 m laterally, that two or three lithic types are encountered within the confines of a single pit—for example, the Greenbrier Pit at locality 25 (Text-figs. 1, 2). This problem is not unique to Virginia, but is characteristic of the Pleistocene and older sediments of the entire Coastal Plain area. Consequently, intra- and interregional correlation is very difficult and investigations in paleoecology and geologic history that are predicated on a sound biostratigraphic framework encounter great difficulties.

Biostratigraphic division for the marine Pleistocene has been demonstrated for the early Pleistocene Bermont Formation (Unit A) of south Florida (Hoerle, 1970; Olsson, 1968). Microfossil division of the Pleistocene Coastal Plain sediments has not been tested extensively to date. Hazel (1977) and Cronin and Hazel (1979) developed a biostratigraphic framework based on ostracodes for the Pliocene and lower Pleistocene of Virginia and northern North Carolina and for the Pliocene and Pleistocene deposits of the Cape Fear Arch region of North and South Carolina, respectively. Cronin (1980) erected a biostratigraphic zonation for the Pleistocene. Because his ostracode-based *Bensonocythere saploensis* Assemblage Zone (Cronin, 1981) includes all of the late Pleistocene as well as a significant part of the middle Pleistocene, it is not yet possible to correlate late Pleistocene events biostratigraphically with any assurance.

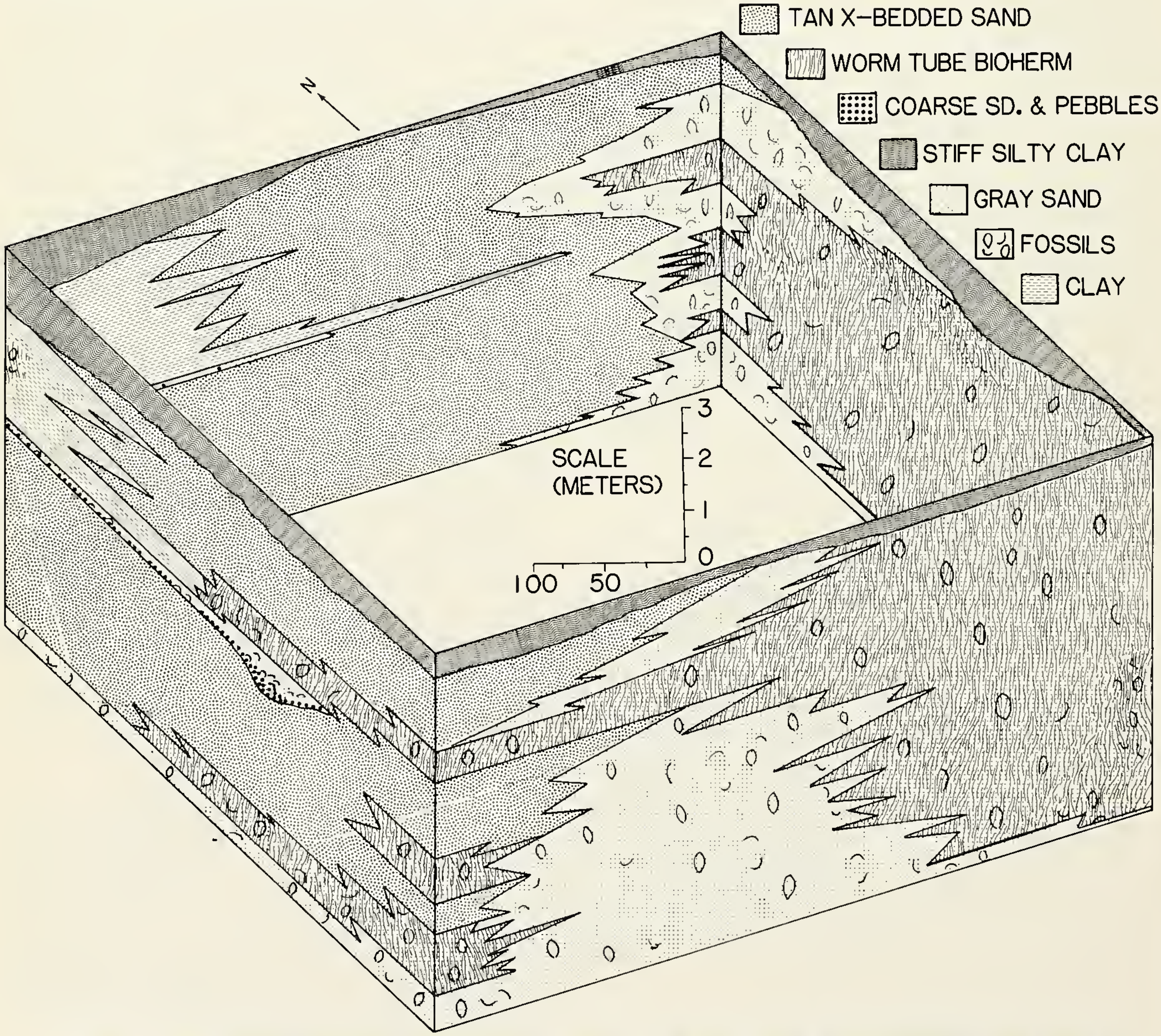
Because the Pleistocene sediments in southeastern Virginia exhibit very rapid lateral change, both parallel and perpendicular to strand lines, attempts to erect lithostratigraphic units have resulted in formations with such complex facies relationships that they cannot be correlated intra- or interregionally with any degree of certainty. The development of chronostratigraphic units requires a degree of precision of time not yet demonstrated for any eastern Coastal Plain Pleistocene section. Superposition, unconformities, and geomorphology have been used to establish relative time relationships within the Virginia Pleistocene. It is apparently on these bases that Oaks and Coch (1973, p. 107) designated their formations as time-stratigraphic units. However, these sediment complexes are transgressive–regressive sequences that should be time-transgressive rather than isochronous. This is one of the fundamental objections that Lowman (1949) raised to the use of "time-stratigraphy" in the Gulf Coast Cenozoic section.



Text-figure 1.—Map of study area, southeastern Virginia, showing locations of collecting localities.

Cyclicity in the Gulf Coastal Plain has long been recognized (Stephenson, 1928). Lowman (1949), objecting to the use of a time-stratigraphic classification, suggested that the stratigraphic framework of that area be defined in terms of regional transgressive–regressive features. Both Lozo and Stricklin (1956), and Young (1963) describe and use this cyclicity in their classifications of the Cretaceous rocks of Texas; Fisher (1964), using depositional patterns, classified the Eocene rocks of the northern Gulf Coastal Plain; and Colquhoun (1969, 1971, 1974) embraces a similar viewpoint in his classification of the Atlantic Coastal Plain sediments of South Carolina. In these studies, the defined cyclic units were described as standard stratigraphic formations. Until recently, Atlantic Coastal Plain Pleistocene formations were determined on the basis of physiographic features such as scarps (Colquhoun, 1974). As Oaks and DuBar (1974, table 5, p. 7) point out, since 1950 there has been a significant change from a "terrace-formation" to a standard stratigraphic formation concept, with geomorphic expression as one of many criteria.

As indicated by Colquhoun (1971, 1974), the most consistent and unifying feature of Pleistocene Coastal Plain sediments is the transgressive–regressive nature of these sediments. The imprint of these diachronous events is the most effective means of clustering local stratigraphic elements into mappable units in southeastern Virginia.

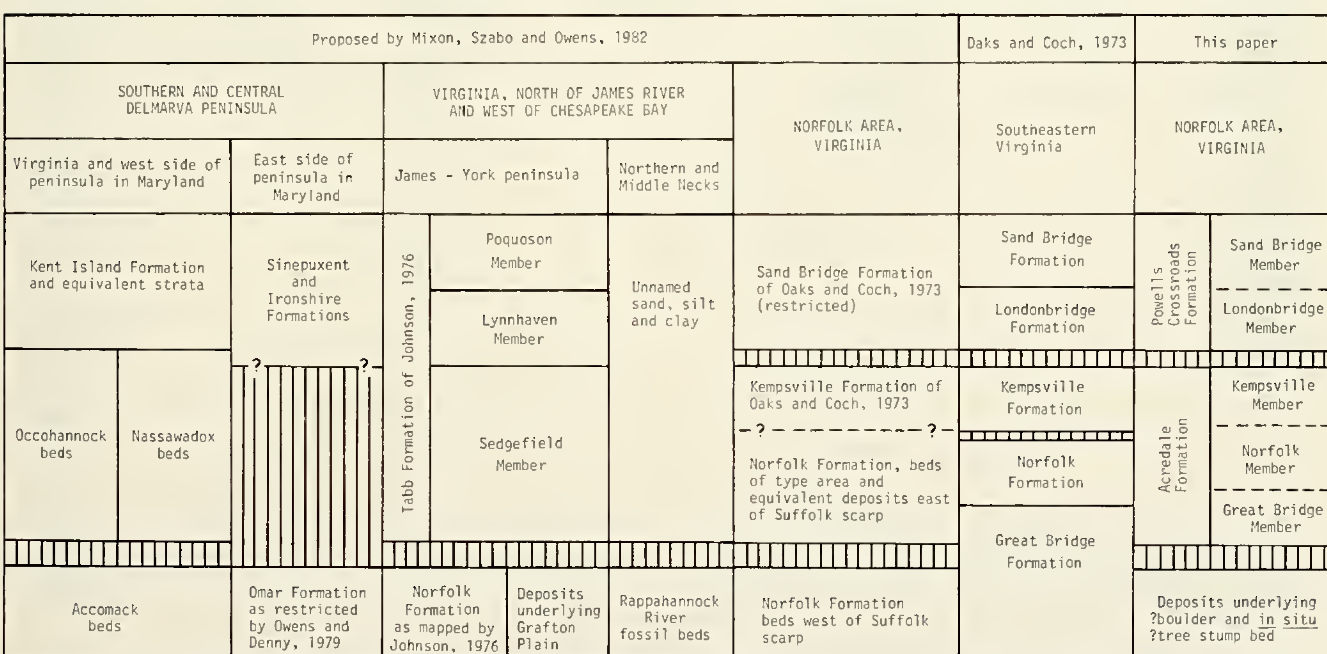


Text-figure 2.—Fence diagram representing the Greenbrier Pit (locality 25), showing complex facies relationships within a small area.

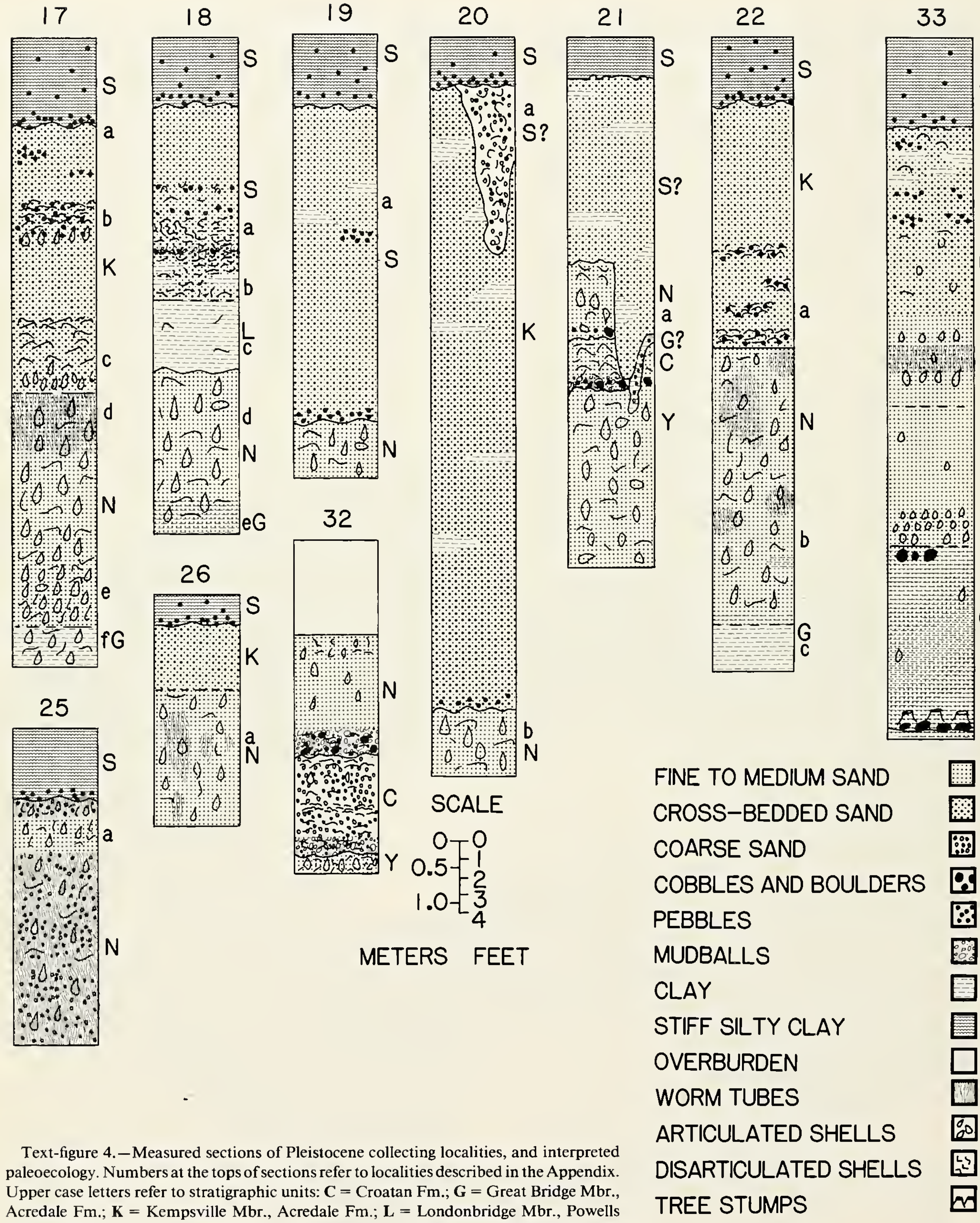
Text-figure 3 is an attempt to show the stratigraphic relationships between the findings of the authors and those of Oaks and Coch (1973) as well as to the tentative stratigraphic correlations proposed by Mixon, Szabo, and Owens (1982). The Great Bridge, Norfolk, and Kempsville formations of Oaks and Coch (1973) consist of laterally and vertically intergrading lithofacies and biofacies of estuarine silty sands, continental shelf sands, and beach to fluvial sands (Text-figs. 1, 4). The vertical succession of these sediments and contained fauna, grading from estuarine silty sands to open ocean shelf sands and beach sands, argue for a single diachronous transgressive–regressive event (Text-figs. 1, 4). Consequently, the Great Bridge, Norfolk and Kempsville formations erected by Oaks and Coch (1973) should be seen not as formations, but rather as locally-significant members. The authors propose that this gradational sequence, mappable at the formational level, be called the Acredale Formation.

The type section of the Acredale Formation is a sand and gravel pit near the municipality of Acredale, City of Virginia Beach, Virginia. It is located on the Kempsville 7.5′ Quadrangle at longitude 76°10′13″W and latitude 36°47′30″N, 0.5 mi southeast of the intersection of Indian River Road and Kempsville Road. A detailed section is provided under locality 17 of the Appendix, and faunal components are listed by beds (17a–f) under this same locality in Table 1. The base of the Acredale Formation is not exposed. Because of this and because mining excavations in the area are ephemeral, with exposures lasting only a few years at best, a currently-exposed reference section is herein established (loc. 33, Appendix; Text-fig. 4). It is located 0.33 mi north of the intersection of Centerville Turnpike and Kempsville Road (Mears Corner) at longitude 76°10′40″W and latitude 36°47′41″N on the Kempsville 7.5′ Quadrangle. At this locality the base of the Acredale Formation is marked by a layer of *in situ* tree stumps and boulders in sharp contact with underlying sediments.

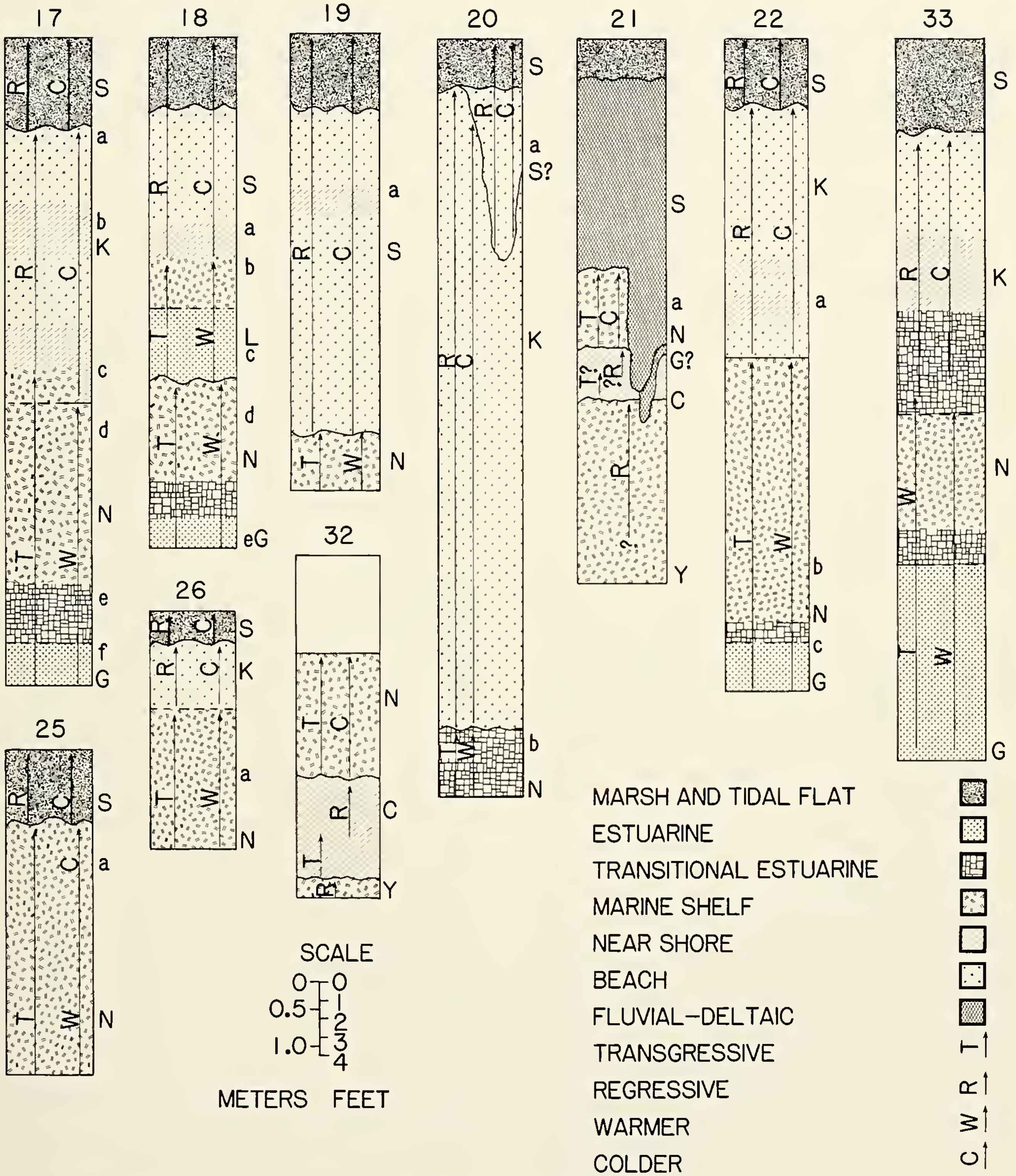
The term Norfolk Formation, proposed by Clark and Miller (1906), was originally based on the fossiliferous strata in the vicinity of South Norfolk (now City of Chesapeake) and was considered of Pleistocene age by Richards (1936). This unit was redefined by Oaks and Coch (1973, p. 70); was used by Johnson and Goodwin (1969) for the middle of three Pleistocene formations recognized on the York–James Peninsula; was partially incorporated by Johnson (1976) into his Tabb Formation, which either overlies or is equivalent to the Sand Bridge Formation of Oaks and Coch (1973); has been tentatively extended into the Delmarva Peninsula (Cronin, 1980); and has been split into a post-140,000 years B.P. Norfolk Formation and a pre-140,000 years B.P. Norfolk Formation (Mixon, Szabo, and Owens, 1982). Mixon, Szabo, and Owens (1982) confine this latter to beds west of the Suffolk scarp and think that they might be equivalent to the Norfolk Formation as mapped by Johnson (1976), to the Rappahannock River beds (Cronin *et al.*, 1981), to the Accomack beds and to the Omar Formation as restricted by Owens and Denny (1979). These relationships are shown in Text-figure 3. Campbell *et al.* (1975) erected a Plio-Pleistocene stratigraphic framework for Virginia, North and South Carolina, and south Florida. Here, the Nor-



Text-figure 3.—Proposed stratigraphic relationships of sediments discussed in this study and in previous work.



Text-figure 4.—Measured sections of Pleistocene collecting localities, and interpreted paleoecology. Numbers at the tops of sections refer to localities described in the Appendix. Upper case letters refer to stratigraphic units: **C** = Croatan Fm.; **G** = Great Bridge Mbr., Acredale Fm.; **K** = Kempsville Mbr., Acredale Fm.; **L** = Londonbridge Mbr., Powells Crossroads Fm.; **N** = Norfolk Mbr., Acredale Fm., **S** = Sand Bridge Mbr., Powells Crossroads Fm.; **Y** = Yorktown Fm. Lowercase letters refer to specific sampling horizons within given sections (see Appendix; Table 1).



folk Formation is considered Sangamon in age and equivalent to the Talbot Formation of North and South Carolina and to the Fort Thompson Formation of Florida. Mixon, Szabo, and Owens (1982), based upon their interpretation of radiometric trends (which suggest differences in diagenetic modification of coralline material), speculate that the type Norfolk beds are equivalent in age to those dated at approximately 95,000 years in South Carolina and to those dated at 125,000 years in the Caribbean area.

Until there is sufficient biostratigraphic and radiometric evidence either for or against the correlative nature of these units, it is prudent to use the term Acredale for beds marking a transgressive–regressive event commonly encountered in southeastern Virginia, east of the Suffolk scarp. This proposed usage allows continuity with established literature, detailed description of local stratigraphy, and the assignment of sediments from isolated cores or outcrops to undifferentiated Acredale when the proper subunit cannot be determined.

Similar gradational lithofacies and biofacies relationships also are found for the Londonbridge and Sand Bridge formations of Oaks and Coch (1973). Consequently, these units are herein recognized as locally significant members. The authors propose that this younger gradational sequence be named the Powells Crossroads Formation.

The type section of the Powells Crossroads Formation is a sand and gravel pit 0.1 mi northeast of the intersection of Kempsville and Holland roads, known as Powells Crossroads and located at longitude 76°8′00″W and latitude 36°50′00″N on the Kempsville 7.5′ Quadrangle. The stratigraphic section is detailed under locality 18 (Appendix) and faunal components are listed under this same locality in Table 1.

Much of the recent chronostratigraphic work postdates the flooding of the Womack Pit (loc. 17; Text-figs. 1, 2, 3), which was used by Oaks and Coch as the type section of the Norfolk Formation. In the adjacent E. V. Williams Ferrel Farm Pit (New Light Pit of Cronin, 1979) located about 0.5 mi west of the Womack Pit (loc. 20; Text-figs. 1, 4), Belknap and Wehmiller (1980) mention an unconformity that separates *Mercenaria* beds, which were protein-dated at about 300,000–350,000 years B.P. and 70,000–90,000 years B.P. These dates imply a hiatus of over 200,000 years (Belknap and Wehmiller, 1980). The lower *Mercenaria* beds (exposed in 1973) are directly correlated to the lower part of the Norfolk Member of Oaks and Coch's (1973) redefined Norfolk Formation at the Womack Pit. However, at Yadkin Pit (loc. 21; Text-figs. 1, 4) Belknap and Wehmiller (1980) reported a protein date of 100,000 years B.P. from shell material in the Norfolk Member. During our field investigation, the unconformity at the Ferrel Farm (New Light) Pit was erosional, with both the upper part of the Norfolk Member and the lower part of the Kempsville Member missing, leaving only the Great Bridge Member and the lower part of the Norfolk Member underlying the unfossiliferous upper part of the Kempsville Member. In the nearby Womack Pit section (loc. 17; Text-figs. 1, 3, 4) lower and upper Norfolk beds are conformable with each other and with the overlying Kempsville Member. Both members at this locality possess in situ *Mercenaria* beds with a serpulid reef commonly ocurring in the upper part of the Norfolk Member. The contact between the Norfolk Member and the Kempsville Member, therefore, varies from gradational, where the reef is not developed, to sharp, where the reef is present. This sharp contact is irregular due to variations in reefal development. Cronin *et al.* (1981) provided a measured section of the Ferrel Farm (New Light) Pit showing that pit expansion subsequent to our (1974) fieldwork has exposed both the upper part of the Norfolk Member with its serpulid reef and the overlying lower part of the Kempsville Member. These stratigraphic relationships are very similar to those found in the previously-mentioned Womack section. Uranium dates (Cronin *et al.*, 1981) obtained at this locality from corals collected more than two m above the serpulid reef and lying within the lower part of the Kempsville Member yielded a reading of 74,000 ± 4,000 years. In addition, Cronin *et al.* (1981) report a uranium date of 75,000 ± 5,000 years at a nearby pit (Mears Pit), which was obtained from corals collected in the serpulid reef of the Norfolk Member. Similar radiometric dates of corals from this unit are reported by Mixon, Szabo, and Owens (1982). It appears likely that the unconformity cited by Belknap and Wehmiller (1980) is the contact between the reef facies in the Norfolk Member and the overlying gradational Kempsville Member. That being the case, the uranium dates are in conformity with the litho- and biostratigraphy, and the 300,000–350,000 year protein date is herein discounted. Cronin *et al.* (1981), tentatively assigned the clusters of uranium-series dates averaging 72,000 ± 5,000 years (Norfolk and Kempsville members, Acredale Formation) to isotope stage 5a (Emiliani, 1955) and gave an estimated relative sea level of 4 to 10 m above mean sea level (ASL) based upon *in situ* oysters, beach sands, cross-bedding, and nearshore faunal assemblages. It is interesting to note that the faunal assemblages analyzed in our study support this estimate, except for our localities 18b and 18d. These localities have a faunal assemblage indicating more open-marine conditions and possible higher paleo sea levels.

That our southeastern marine Pleistocene deposits might preserve a patchwork of chronostratigraphically-diverse beds is supported by the growing data base of absolute dates (Mixon, Szabo, and Owens, 1982; Cronin *et al.*, 1981). Haq, Berggren, and Van Couvering (1977) observe that the 100,000 year periodicity (Hays, Imbrie, and Shackleton, 1976) is superimposed on a larger harmonic of roughly 500,000 years, which has produced exceptional glacial advances at 1.5, 0.9, 0.6, and 0.3 million years. We assume that the standard

Table 2.—Faunal listing by taxonomic group occurring in the Great Bridge Member of the Acredale Formation showing zoogeographic distribution by subprovince using the number and percent of species occurrences within each taxonomic group.

Taxonomic group		*range uncertain*	*extinct*	*exclusively northern Virginian*	*southern Virginian*	*exclusively Carolinian*	*total*
Foraminifera	#	3	0	2	18	0	23
	%	13	0	9	78	0	
Porifera	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Coelenterata	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Bryozoa	#	1	0	0	3	1	5
	%	0	0	0	0	0	
Annelida	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Mollusca	#	0	0	0	52	8	60
	%	0	0	0	86	14	
Ostracoda	#	—	—	—	—	—	—
	%			.			
Larger Crustacea	#	0	0	0	1	0	1
	%	0	0	0	100	0	
Echinodermata	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Vertebrata	#	0	0	0	4	0	4
	%	0	0	0	100	0	
Totals	#	4	0	2	78	9	93
	%	4	0	2	83	10	

North American continental Pleistocene epochs coincide with these larger cycles and that the Virginia marine Pleistocene section discussed herein approximates that expression.

Age assignments and correlation of Pleistocene units will probably remain controversial, given the lack of index species and the difficulties and controversies surrounding relevant dating methods.

FAUNAL ANALYSIS AND PALEOECOLOGY

We document 332 species in nine phyla (Tables 1, 2, 12), making the fauna one of the most thoroughly studied in the southeastern United States. Modern zoogeographic distribution by phylum and member are listed in Tables 2–9. The upper part of the Norfolk Member and the lower part of the Kempsville Member are the only intervals for which ostracode data are available. Consequently, subsequent tables and analyses compile the faunas with and without the ostracode data for comparative purposes. Faunal totals by stratigraphic member and phylum are listed in Tables 10 and 11. Diagnosis of measured sections and the inferred paleoecology can be found in Text-figure 4. Measured sections can be found in the locality listing in the Appendix.

The Sangamon interstadial containing the Acredale and the unconformably-overlying Powells Crossroads formations is well developed in southeastern Virginia. The Acredale Formation can be divided into three units, which, in ascending order, are the Great Bridge Member, the Norfolk Member, and the Kempsville Member.

The Powells Crossroads Formation may be divided into the Londonbridge and overlying Sand Bridge members.

ACREDALE FORMATION

Great Bridge Member.—The Great Bridge Member is the lowermost unit to be exposed by pit excavations in the study area (locs. 17f, 18e, 22c, and 33; Text-figs. 1, 4; Tables 1, 2). Typically, this unit has a matrix of silty to sandy clay and a sparse macrofossil assemblage (Table 2) with *Mulina* Gray, 1837 and *Tagelus* Gray, 1847 common and reefs of *Crassostrea* Sacco, 1897 locally important. Valves of *Cyrtopleura costata* (Linné, 1758) were often found paired and in living position. Great Bridge bryozoans and foraminifers are dominated by *Electra monostachys* (Busk, 1854), *Membranipora tenuis* Desor, 1848, and *Elphidium clavatum* Cushman, 1930.

In addition to *E. monostachys,* and *M. tenuis,* the other bryozoans, *Microporella ciliata* (Pallas, 1766), *Schizoporella errata* (Waters, 1878), and *Discoporella umbellata depressa* (Conrad, 1841), are either comparatively rare occurrences found on fragments of shell material, especially on worm tubes (*Hydroides* sp.) or

Table 3.—Faunal listing by taxonomic group occurring in the lower part of the Norfolk Member of the Acredale Formation, showing zoogeographic distribution by subprovince using the number and percent of species occurrences within each taxonomic group.

Taxonomic group		*range uncertain*	*extinct*	*exclusively northern Virginian*	*southern Virginian*	*exclusively Carolinian*	*total*
Foraminifera	#	6	0	3	21	0	30
	%	20	0	10	70	0	
Porifera	#	0	0	0	1	0	1
	%	0	0	0	100	0	
Coelenterata	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Bryozoa	#	2	0	0	10	2	14
	%	15	0	0	69	14	
Annelida	#	0	0	0	2	0	2
	%	0	0	0	100	0	
Mollusca	#	1	1	1	58	8	69
	%	1.5	1.5	1.5	84	12	
Ostracoda	#	—	—	—	—	—	—
	%						
Larger Crustacea	#	0	0	0	2	0	2
	%	0	0	0	100	0	
Echinodermata	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Vertebrata	#	1	0	0	0	0	1
	%		100	0	0	0	0
Totals	#	10	1	4	93	10	119
		9	1	3	78	9	

fragments to nearly whole cups of the free form, *Discoporella umbellata depressa.* These forms are not typical estuarine species (Schopf, 1973). However, the condition of the material, as well as the fragmented nature of the bryozoans themselves, indicate that they were transported or reworked. Schopf (1973, p. 255), in analyzing reported occurrences (Osburn, 1933, 1944) of Chesapeake Bay bryozoans, cites what may be an analogous situation,

> . . . considering the nature of the currents, and the salt wedge, there appears to be good reason for believing that avicularia-bearing, normal-salinity species were not indigenous to lower salinity waters of Chesapeake Bay but were in fact transported to the place where they were collected.

The dominant fauna, exhibiting low species diversity and small population size, is characteristic of reduced salnities in an estuarine environment. Judging from the number of southern elements in the fauna (Tables 2, 10, 12; Text-fig. 6), Great Bridge water temperatures were somewhat warmer than the present but slightly cooler than those inferred for the overlying Norfolk Member.

Norfolk Member.—As the sea advanced, the Great Bridge estuarine facies was pushed progressively inland, gradually giving way in the Kempsville area to the clayey to silty fine sands of the lower part of the Norfolk Member. A macrofauna (locs. 17e, 20b; Text-figs. 1, 4; Tables 1, 3) dominated by articulated bivalves referable to *Tagelus* Gray, 1847, *Cyrtopleura* Tryon, 1862, and *Macoma* Leach, 1817 still requires estuarine salinities, but the assemblage becomes surprisingly rich (Table 4), suggesting more open water such as a bay or inlet, particularly at locality 20b. The dominant microfauna includes the bryozoans *Electra monostachys* (Busk, 1854), *Membranipora tenuis* Desor, 1848, and *Schizoporella errata* (Waters, 1878), and such foraminifers as *Elphidium clavatum* Cushman, 1930, *E. galvestonense* Kornfield, 1931, *E. tumidum* Natland, 1938, *Quinqueloculina seminula* (Linné, 1758), and *Q. lamarckiana* d'Orbigny, 1839.

With continued transgression, the lower Norfolk estuarine environment was gradually replaced by a sublittoral shelf environment. This part of the member (locs. 17d, 18d, 21, 22b, 25, 26, 27, 28, and 30; Text-figs. 1, 4; Tables 1, 4) marks the peak of the transgressive pulse with transitional marine faunas such as those found at localities 17d, 22b, and 25 giving way to more open marine faunas such as those found at localities 18d, 21, 26, 27, 28, and 30 (Table 1). It is typified by the loss of diagnostic estuarine species, domination by marine species, and a substantial increase in species diversity (Table 4). In the upper part of the Norfolk Member, there is an increase in the number of colder water species with a concomitant decrease in the number of warmer water species (Text-fig. 6; Tables 3, 4, 12) as well as the development of

Table 4.—Faunal listing by taxonomic group occurring in the upper part of the Norfolk Member of the Acredale Formation, showing zoogeographic distribution by subprovince using the number and percent of species occurrences within each taxonomic group.

Taxonomic group		*range uncertain*	*extinct*	*exclusively northern Virginian*	*southern Virginian*	*exclusively Carolinian*	*total*
Foraminifera	#	12	0	3	26	0	41
	%	29	0	7	63	0	
Porifera	#	1	0	0	1	0	2
	%	50	0	0	50	0	
Coelenterata	#	0	0	0	1	0	1
	%	0	0	0	100	0	
Bryozoa	#	2	0	0	10	2	14
	%	13	0	0	0	73	13
Annelida	#	0	0	0	2	0	2
	%	0	0	0	100	0	
Mollusca	#	0	1	4	76	7	88
	%	0	1	4	86	8	
Ostracoda	#	1	9	1	65	5	81
	%	1	11	1	80	6	
Larger Crustacea	#	1	0	0	13	1	15
	%	7	0	0	87	7	
Echinodermata	#	0	0	0	3	0	3
	%		0	0	0	100	0
Vertebrata	#	1	0	0	5	0	6
	%	17	0	0	83	0	
Totals	#	18	10	8	202	15	253
	%	7	4	3	80	6	

an extensive serpulid worm-rock reef (*Hydroides* spp.), particularly in the Kempsville area. The reef structures provided habitat for bivalves, crabs, and other large crustaceans and a solid substrate for a diverse bryozoan assemblage. Between these reefs, a diverse open-shelf assemblage is found in a blue-gray, fine-grained, quartz sand. In the more western localities (locs. 21, 25, 27, and 28; Text-figs. 1, 2, 4; Table 1), the macro- and microfauna show an increase both in relatively cool water and in estuarine species. This trend first makes itself apparent in the Norfolk Member at the Greenbrier Pit (loc. 25; Text-figs. 1, 2, 4; Tables, 1, 4) approximately 4.8 km (5 mi) west of the Kempsville area. At this locality, the serpulid reef is less extensively developed in its upper portion. There is also a noticeable decrease in overall species diversity. However within this faunal assemblage there is an increase in the number of estuarine species, and a slight increase in the number of cooler water forms (Table 1). The frequent occurrence of the cool-water bryozoan *Cryptosula pallasiana* (Moll, 1803), the dominant eurythermal aspect of the entire fauna, and a reduction in warm-water associated foraminifers, bryozoans, and molluscs indicate temperatures cooler than their stratigraphic equivalents to the east. The westward trend to more brackish and cooler conditions is accentuated at the Yadkin Pit (loc. 21; Text-figs. 1, 4; Table 1) 24 km (15 mi) west of the Kempsville area. Estuarine or very shallow sublittoral conditions are indicated by commonly-occurring bivalves such as *Ensis directus* (Conrad, 1843), *Mulinia lateralis* (Say, 1822), and by fragments of *Ischadium recurvum* (Rafinesque, 1820). The entire macro- and microfauna is much reduced both in species diversity and population size. The bryozoan population is dominated by *Membranipora tenuis* Desor, 1848, a typical estuarine species. Other bryozoan occurrences are rare, consisting of worn and abraded fragments. The foraminiferal population is dominated by *Elphidium* of which *E. clavatum* Cushman, 1930, and *E. brooklynense* Shupack, 1934, are the dominant species. Reduced temperatures are indicated by the occurrence of *Cyclocardia borealis* (Conrad, 1831), and by the foraminifers *Pseudopolymorphina* cf. *novangliae* (Cushman, 1923) and *Bucella frigida* (Cushman, 1922).

This westward cooling in the upper part of the Norfolk may reflect a time lag between maximum sea level and maximum temperature, such as was demonstrated for the late Wisconsinan (Balsam and Heusser, 1976), or it may reflect a normal faunal response to more rigorous, nearshore seasonal temperature fluctuations. Considering the diminution in size and extent of the upper portion of the serpulid reef at locality 25 and its faunal components and the relative increase in cool-water fauna within the upper part of the Norfolk Member at other localities, the first hypothesis is preferred.

Table 5.—Faunal listing by taxonomic group occurring in the lower part of the Kempsville Member of the Acredale Formation, showing zoogeographic distribution by subprovince using the number and percent of species occurrences within each taxonomic group.

Taxonomic group		*range uncertain*	*extinct*	*exclusively northern Virginian*	*southern Virginian*	*exclusively Carolinian*	*total*
Foraminifera	#	4	0	4	20	0	28
	%	14	0	14	71	0	
Porifera	#	0	0	0	1	0	1
	%	0	0	0	100	0	
Coelenterata	#	0	0	0	1	0	1
	%	0	0	0	100	0	
Bryozoa	#	1	0	0	6	1	8
	%	12	0	0	75	12	
Annelida	#	0	0	0	2	0	2
	%	0	0	0	100	0	
Mollusca	#	1	3	3	66	8	81
	%	1	4	4	81	10	
Ostracoda	#	1	3	1	39	3	47
	%	2	6	2	83	6	
Larger Crustacea	#	0	0	0	9	1	10
	%	0	0	0	90	10	
Echinodermata	#	0	0	0	1	0	1
	%	0	0	0	100	0	
Vertebrata	#	0	0	1	12	0	13
	%	0	0	8	92	0	
Totals	#	7	6	9	157	13	192
	%	4	3	5	82	7	

In addition to the above-mentioned lag between sea level and temperature maxima, the preferred interpretation also implies time transgression of the deposit. Inferred temperature changes through the stratigraphic sections under consideration are discussed in a later section of this paper.

Kempsville Member.—The sublittoral, open-shelf environment and gradual cooling initiated during the deposition of the upper part of the Norfolk Member was continued during the deposition of the gray, fine sand of the lower part of the Kempsville Member (locs. 17c, 22a; "*Mactra*" bed of Oaks and Coch, 1973, p. 81; Text-figs. 1, 4; Tables 1, 5). Diversity remained high (Table 5) with warm-water marine species still predominating but with cold-water forms continuing to increase. Regression and shallowing is reflected in the gradual change from fine to coarse sand and in the presence of worn, single valves of *Crassostrea virginica* (Gmelin, 1791). Increased energy is indicated by the predominance of large, concave-down bivalve shells, and in the upward gradation of lithofacies into the nearshore and beach sands and channel fills of the upper part of the Kempsville Member.

The upper part of the Kempsville Member at Womack Pit consists of what appears to be an overlying beach ridge at 18 ft above sea level containing molds of *Spisula solidissima* (Dillwyn, 1817) (locs. 17a, 17b; Text-figs. 1, 4; Tables 1, 6) and an underlying shallow-water sand and channel gravel sequence containing such northern, cold-water species as *Cryptosula pallasiana* (Moll, 1803), *Cyclocardia borealis* (Conrad, 1831), *Astarte castanea* (Say, 1822), *Buccinum undatum undatum* Linné, 1758, *Colus pygmaeus* (Gould, 1841), walrus, great auk, murre, and breeding populations of seals and gannets. Southern elements (Table 6) are not eliminated, but are reduced in number, often worn, and possibly reworked. Although sea level was elevated, inferred temperatures for the upper part of the Kempsville Member are lower than those of the present Virginia coast. This conclusion was first drawn on vertebrate evidence by Ray *et al.* (1968) but then was rejected because of the presumably contradictory invertebrate evidence. However, the invertebrate fauna directly associated with the boreal vertebrates at Womack Pit show a similar increase in boreal influence.

Oaks and Coch (1973) defined the contact between their Norfolk and Kempsville formations as the top of the serpulid reef in the type localities at the Womack Pit. This is a biofacies contact. The non-annelid fossils demonstrate faunal continuity across the boundary (Text-fig. 4). In this study, we have used the same annelid-reef boundary between the Norfolk and Kempsville members for continuity with Oaks and Coch's (1973) basic stratigraphic framework and arbitrarily for delineating sea levels and sea temperature changes.

Table 6.—Faunal listing by taxonomic group occurring in the upper part of the Kempsville Member of the Acredale Formation, showing zoogeographic distribution by subprovince using the number and percent of species occurrences within each taxonomic group.

Taxonomic group		*range uncertain*	*extinct*	*exclusively northern Virginian*	*southern Virginian*	*exclusively Carolinian*	*total*
Foraminifera	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Porifera	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Coelenterata	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Bryozoa	#	1	0	0	0	0	1
	%	100	0	0	0	0	
Annelida	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Mollusca	#	0	3	5	41	3	52
	%	0	6	10	78	6	
Ostracoda	#	—	—	—	—	—	—
	%						
Larger Crustacea	#	2	0	0	5	0	7
	%	29	0	0	71	0	
Echinodermata	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Vertebrata	#	1	1	5	12	0	19
	%	5	5	26	63	0	
Totals	#	4	4	10	58	3	79
	%	5	5	13	73	4	

The fauna at the Owl Creek Marina (loc. 23; Table 1), the easternmost of our localities, deserves separate mention. Fossiliferous sand was encountered at approximately 40 ft below sea level during pump-dredging operations to replenish eroding tourist beaches. The fauna was dominated by *Astarte castanea* (Say, 1822), with rarer *Cyclocardia borealis* (Conrad, 1831), *Lunatia heros* (Say, 1822), *Nassarius trivittatus* (Say, 1822), and *Atractodon stonei* (Pilsbry, 1893). These are exclusively cold-water species and hence are somewhat younger than those found at the Womack Pit (loc. 17b). Daniel Belknap kindly tested a valve of a species of the mollusk *Astarte* from Owl Creek by protein-dating techniques and found a D/L Leucine ratio of 0.209, which he interpreted as 60,000 ± 20,000 years B.P. At 40 ft below sea level, this cold-water fauna must underlie the fossiliferous strata encountered in piston cores taken just offshore of Virginia Beach, Virginia (Shideler *et al.*, 1972; Zellner, 1979). All species of the genera reported from these two studies require open-shelf, shallow, sublittoral conditions and relatively warm temperatures. Although both of these papers refer these beds to the Norfolk Formation, the offshore material taken by dredge at Owl Creek is thought to be the seaward equivalent of at least the upper part of the Kempsville Member of the Acredale Formation, while that obtained by piston core is thought to be the seaward equivalent of the Sand Bridge Member of the Powells Crossroads Formation.

POWELLS CROSSROADS FORMATION

The Powells Crossroads Formation consists of the Londonbridge and Sand Bridge members. Evidence for a separate transgression was especially abundant in the Powells Crossroads (now "Mt. Trashmore" recreational area) Pit (loc. 18, Appendix). Here the intervening Kempsville Member is completely removed and the contact between the Norfolk Member and the basal Londonbridge Member is erosional and very sharp. The very diverse fauna of the Norfolk Member at this locality, indicating cool, sublittoral conditions, is in marked contrast to the low diversity, marsh to estuarine, warmer-water fauna found in the Londonbridge Member of the Powells Crossroads Formation (cf. locs. 18c, 18d, Table 1). The Londonbridge fauna and silt-clay sediments typify inner estuarine deposition, the leading facies in a transgressive sequence. Core evidence (Oaks and Coch, 1973) indicated that the Londonbridge and fossiliferous Sand Bridge members overlie truncated Kempsville deposits to the west of the Powells Crossroads Pit before pinching out at an elevation of about 21 ft.

Londonbridge Member.—The Londonbridge silty clays bear a striking resemblance to the Great Bridge sediments but have a fauna of only 14 species (loc. 18c; Text-figs. 1, 4; Tables 1, 7). Like the Great Bridge sediments, the Londonbridge represents the marsh and estuarine deposits of a warm transgressing sea (Table

Table 7.—Faunal listing by taxonomic group occurring in the Londonbridge Member of the Powells Crossroads Formation, showing zoogeographic distribution by subprovince using the number and percent of species occurrences within each taxonomic group.

Taxonomic group		*range uncertain*	*extinct*	*exclusively northern Virginian*	*southern Virginian*	*exclusively Carolinian*	*total*
Foraminifera	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Porifera	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Coelenterata	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Bryozoa	#	·0	0	0	1	1	2
	%	0	0	0	50	50	
Annelida	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Mollusca	#	0	0	1	11	0	12
	%	0	0	17	83	0	
Ostracoda	#	—	—	—	—	—	—
	%						
Larger Crustacea	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Echinodermata	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Vertebrata	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Totals	#	0	0	1	12	1	14
	%	0	0	7	86	7	

7). The free-living marine cup bryozoans *Cupuladria biporosa* (Canu and Bassler, 1923) and *Discoporella umbellata depressa* (Conrad, 1841) in this stratigraphic unit seem to be transported, since fragmented and whole specimens were found in a thin lens of medium to coarse sand that appears to be part of a wash-over deposit.

Sand Bridge Member.—The basal portion of this unit is a gray, silty sand containing lenses of clay and fossil hash as well as a bay to tidal fauna that consists predominantly of *Ensis directus* (Conrad, 1843), *Divalinga quadrisulcata* (d'Orbigny, 1842), and *Nucula proxima* Say, 1820. These sediments grade upward into gray sands that contain a rich and diverse sublittoral assemblage. Commonly-occurring *Nuculana acuta* (Conrad, 1832), *Argopecten gibbus* (Linné, 1758), *Dinocardium robustum* (Lightfoot, 1786), *Pitar morrhuana* (Linsley, 1845), *Pandora gouldiana* (Dall, 1886), *Periploma leana* (Conrad, 1831), *Circulus liratus* (Verrill, 1882), *Epitonium angulatum* (Say, 1830), *Lunatia heros* (Say, 1822), *Atractodon stonei* (Pilsbry, 1893), *Terebra concava* (Say, 1827), and *T. dislocata* (Say, 1822), give the lower part of the Sand Bridge Member an immediately recognizable character because these species are consistently rare in the other members. In addition to these, this lower part of the Sand Bridge Member also contains well-preserved individuals of molluscan species such as *Argopecten gibbus, Mercenaria campechiensis* (Gmelin, 1790), *Circulus liratus, Epitonium multistriatum* (Say, 1826), *Prunum roseidum* (Redfield, 1860), *Kurtziella cerina* (Kurtz and Stimpson, 1851); bryozoan species such as *Cupuladria owenii* (Gray, 1828), *Discoporella umbellata* (Conrad, 1841), *Schizoporella errata* (Waters, 1878), *Hippoporida calcarea* (Smitt, 1873), *Cryptosula pallasiana* (Moll, 1803); and foraminifers such as *Quinqueloculina lamarckiana* (d'Orbigny, 1839), *Elphidium articulatum* (d'Orbigny, 1839), *E. discoidale* (d'Orbigny, 1839). These faunal elements, found in the gray sands of the lower part of the Sand Bridge Member at localities 18b and 20a (Text-figs. 1, 4; Tables 1, 8), have southern affinities and indicate an open marine environment with possible water depths ranging from 5 to 30 m. As noted previously, fossiliferous material encountered in piston cores just offshore appears to be the marine equivalent of the Sand Bridge Member.

The open-marine deposits of the lower part of the Sand Bridge Member grade upward into deposits that contain a fauna typical of an intertidal and very shallow nearshore environment. Here, the upper part of the Sand Bridge Member is characterized by coarser, commonly cross-bedded sands that contain a fauna dominated by *Mulinia lateralis* (Say, 1822) and *Donax roemeri protracta* (Conrad, 1849) (locs. 18a, 19; Text-figs. 1, 4; Tables 1, 9).

This part of the Sand Bridge Member was mapped by Oaks and Coch (1973) as unfossiliferous beach and sheet sands. Both localities were visibly part of beach

Table 8.—Faunal listing by taxonomic group occurring in the lower part of the Sand Bridge Member of the Powells Crossroads Formation, showing zoogeographic distribution by subprovince using the number and percent of species occurrences within each taxonomic group.

Taxonomic group		*range uncertain*	*extinct*	*exclusively northern Virginian*	*southern Virginian*	*exclusively Carolinian*	*total*
Foraminifera	#	4	0	4	21	0	29
	%	14	0	14	72	0	
Porifera	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Coelenterata	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Bryozoa	#	2	0	0	4	2	8
	%	25	0	0	50	25	
Annelida	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Mollusca	#	0	1	2	53	6	62
	%	0	2	3	85	10	
Ostracoda	#	—	—	—	—	—	—
	%						
Larger Crustacea	#	0	0	0	2	0	2
	%	0	0	0	100	0	
Echinodermata	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Vertebrata	#	0	0	0	1	0	1
	%	0	0	0	100	0	
Totals	#	6	1	6	81	8	102
	%	6	1	6	79	8	

Table 9.—Faunal listing by taxonomic group occurring in the upper part of the Sand Bridge Member of the Powells Crossroads Formation, showing zoogeographic distribution by subprovince using the number and percent of species occurrences within each taxonomic group.

Taxonomic group		*range uncertain*	*extinct*	*exclusively northern Virginian*	*southern Virginian*	*exclusively Carolinian*	*total*
Foraminifera	#	2	0	3	13	0	18
	%	11	0	17	72	0	
Porifera	#	0	0	0	1	0	1
	%	0	0	0	100	0	
Coelenterata	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Bryozoa	#	1	0	0	2	1	4
	%	25	0	0	50	25	
Annelida	#	0	0	0	1	0	1
	%	0	0	0	100	0	
Mollusca	#	0	3	1	3	4	1
	%	0	5	2	87	7	
Ostracoda	#	—	—	—	—	—	—
	%						
Larger Crustacea	#	0	0	0	2	0	2
	%	0	0	0	100	0	
Echinodermata	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Vertebrata	#	0	0	0	0	0	0
	%	0	0	0	0	0	
Totals	#	3	3	4	72	5	87
	%	3	3	5	83	6	

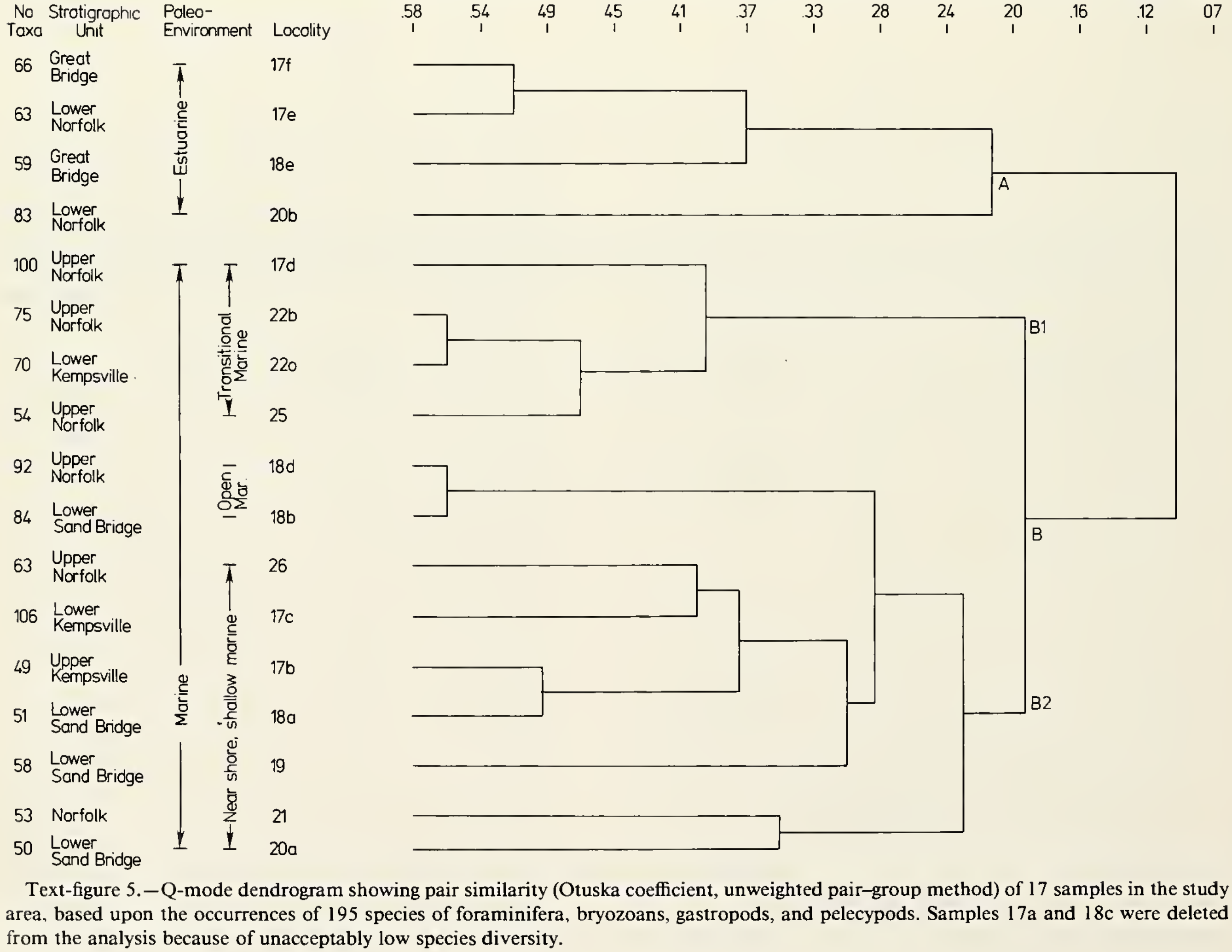
complexes, with the Zahyer (Pavab) Pit (loc. 19) appearing to be part of a washover fan.

CLUSTER ANALYSIS

In order to assess the validity of our paleoecologic interpretations, we conducted an independent analysis of the fauna using binary (presence–absence) coefficients and cluster analysis. The unweighted pair–group method was employed in the Q-mode clustering technique using the Otsuka coefficient. This similarity coefficient is defined (Cheetham and Hazel, 1969) as:

$$\frac{C}{\sqrt{N_1 N_2}}$$

where C equals the number of taxa in both units being compared; N_1 equals C plus all taxa that are present in the first unit, but not the second; and N_2 equals C plus all taxa present in the second unit, but not the first (see Cheetham and Hazel, 1969; Sokal and Sneath, 1963; and Hazel, 1970 for comparisons and discussions of similarity coefficients). The resulting dendrogram (Text-fig. 5) matches our paleoecologic analysis very well. Samples 17f, 17e, 18c, and 20b from the Great Bridge Member and the lower part of the Norfolk Member form cluster A, representing an estuarine fauna. The remaining samples from several different members and formations form cluster B, which represents a variety of more marine environments. Within this large cluster there are several smaller groups. Subcluster B1 contains localities 17d, 22b, 22a, and 25 from the Norfolk and Kempsville members. These localities have faunas representing transitional marine environments such as open-bay. An exception appears to be sample 22a from the Kempsville Member, which the authors have called a shallow to nearshore, marine deposit. The sharp basal contact of this unit with the underlying Norfolk Member, along with the lenses and beds of pebbles, broken and abraded shell material, and disarticulated shells within the Kempsville Member, suggests reworking of a part of the Norfolk Member and incorporation of some of its transitional



Text-figure 5.—Q-mode dendrogram showing pair similarity (Otuska coefficient, unweighted pair–group method) of 17 samples in the study area, based upon the occurrences of 195 species of foraminifera, bryozoans, gastropods, and pelecypods. Samples 17a and 18c were deleted from the analysis because of unacceptably low species diversity.

marine fauna into the Kempsville Member. The preservation of this reworked material would cause this sample to cluster where it did because unweighted binary coefficients were used.

Subcluster B2 contains samples representing marine environments. Of these samples, 18d from the upper part of the Norfolk Member and 18b from the lower part of the Sand Bridge Member represent marine shelf environments and group closely together. The remaining samples, except for those from localities 20a and 21, represent shallow to nearshore marine environments. Sample 20a represents a reworked deposit found in a channel cut into the Norfolk and Kempsville members, while sample 21 represents a fauna from an environment that ranged from bay to very shallow, sublittoral. It should be noted that within each of the clusters, the various stratigraphic units studied are grouped together according to biofacies, irrespective of stratigraphic position, both between and within the two transgressive–regressive formations. The range-through method (Cheetham and Deboo, 1973) was used in an attempt to reduce the biofacies influence, but had little effect upon the cluster pattern.

TEMPERATURE AND SEA LEVEL

The previous discussions in this paper have centered around developing a sequence of events for two late Pleistocene transgressions and are based upon paleoecologic analysis of an extensive fauna. Part of this analysis used inferred temperature regimes of the observed fauna.

Temperature patterns for the Pleistocene sections in the study area are based on cumulative recent distributional records. Recent distributional ranges for 294 of the 332 fossil taxa are recorded in Table 1. The ostracode data are deleted from the temperature analysis because Valentine (1971) studied the Norfolk Member only, rather than the entire stratigraphic sequence representing the Acredale and Powells Crossroads formations. This leaves 223 species for which modern ranges are reasonably well known. However, the ostracode data of Valentine (1971) and Cronin (1979) do lend additional support to the inferred temperature analysis. The only section that Valentine (1971) sampled from both the lower and upper parts of the Norfolk Member is at his locality P2, which is the same as our locality 22 (Toy Avenue Pit, Appendix). The sample (Valentine, 1971; loc. P2–3) from the lower 3 ft of the Norfolk Member has a preponderance of ostracodes that today range both north and south of Cape Hatteras, with just a few species that are either exclusively northern or southern. His samples, stratigraphically higher in the Norfolk Member (Valentine, 1971; locs. P2–2 and P2–1, 5 ft and 3 ft from the top, respectively), indicate an increase in the abundance and diversity of colder water ostracodes. Such cold-water species as *Finmarchinella finmarchica* (Sars, 1865), *Cytheridea* sp. A of Valentine, 1971, *Leptocythere angusta* (Blake, 1933), *Muellerina canadensis* (Brady, 1870), *Muellerina* aff. *Muellerina lienenklausi* (Ulrich and Bassler, 1904), appear for the first time, while ostracodes of southern affinities are absent in the upper portions of this section. Ostracode data from Cronin's (1979) locality 4 (which is the same as the loc. 2 illustrated by Cronin *et al.* (1981), and is the same as our loc. 20, but was sampled after pit expansion and subsequent to our fieldwork) also lends support to this analysis. In his (Cronin, 1979) sample 6 of locality 4 from the Norfolk Member, 15 species were recorded, of which 14 have well-documented geographic ranges. Of these, eight species (57%) today range north and south of Cape Hatteras; five species (35%) are confined south of this geographic boundary; and one species (7%) lives north of Cape Hatteras. His (Cronin, 1979) sample 175 from the same locality is stratigraphically higher than his sample 6. It lies within the Kempsville Member and contains 26 recorded species. Of these, 19 species (73%) today range north and south of Cape Hatteras; three species (11%) are confined to the south; and three species (11%) are confined to the north of this boundary. In addition to the reduction of warm-water ostracodes and an increase in colder-water forms in the higher parts of the Acredale Formation, Cronin has also tentatively identified a juvenile carapace as *Cythere lutea* Mueller, 1875, another cold-water ostracode, from sample 175 (oral commun., 1982). Cronin (1979) did not use this species originally when he developed latitudinal and temperature ranges for the ostracode species found in sample 175.

Relative temperatures can be calculated from our data. One method used for planktonic foraminifera (Ruddiman, 1971) has the formula:

$$(1) \qquad \mathbf{TR} = \left[\frac{\text{cool sp. \%} - \text{warm sp. \%}}{\text{cool sp. \%} + \text{warm sp. \%}}\right] \times 100$$

where **TR** is relative temperature. Because the number of exclusively cold or warm species is small relative to the total fauna studied, the authors devised another method to calculate relative temperature that would not be dependent upon the anomalous occurrences of rare forms:

$$(2) \qquad \mathbf{TR} = \%\text{C} - \frac{(\%\text{B} + \%\text{NV})}{2}$$

where **TR** is relative temperature; **%C** is the percentage of fossil species that range southward into the Carolinian Province; **%B** is the percentage of fossil species also ranging northward into the Boreal Province; and

Table 10.—Faunal totals by stratigraphic unit and zoogeographic province, showing distribution by number and percent of species occurrences for all taxonomic groups.

Stratigraphic unit		range uncertain	extinct	exclusively northern Virginian	southern Virginian	exclusively Carolinian	total
Powells Crossroads Formation							
Upper Sand Bridge Member	#	3	3	4	71	5	86
	%	3	3	5	83	6	
Lower Sand Bridge Member	#	6	1	6	82	8	103
	%	6	1	6	79	8	
Londonbridge Member	#	0	0	1	12	1	14
	%		0	0	7	86	7
Acredale Formation							
Upper Kempsville Member	#	4	4	10	58	3	79
	%	5	5	13	73	4	
Lower Kempsville Member	#	6	3	8	118	10	145
	%	4	2	5	81	7	
Upper Norfolk Member	#	16	1	7	137	10	172
	%	9	1	4	80	6	
Lower Norfolk Member	#	10	1	4	94	10	122
	%	9	1	3	78	9	
Great Bridge Member	#	1	0	2	78	9	93
	%	1	0	2	83	10	
Total	#	22	7	18	180	24	251
	%	9	3	7	72	10	

Table 11.—Faunal totals by taxonomic group and zoogeographic province for all stratigraphic units, showing distribution by number and percent of species occurrences.

Taxonomic group		range uncertain	extinct	exclusively northern Virginian	southern Virginian	exclusively Carolinian	total
Foraminifera	#	12	0	4	26	0	42
	%	29	0	10	62	0	
Porifera	#	1	0	0	1	0	2
	%	50	0	0	50	0	
Coelenterata	#	0	0	0	1	0	1
	%	0	0	0	100	0	
Bryozoa	#	2	0	0	11	2	15
	%	13	0	0	74	13	
Annelida	#	0	0	0	2	0	2
	%	0	0	0	100	0	
Mollusca	#	1	5	9	102	21	138
	%	1	4	7	74	15	
Ostracoda	#	1	9	1	65	5	81
	%	1	11	1	80	6	
Larger Crustacea	#	4	0	0	14	1	19
	%	21	0	0	74	5	
Echinodermata	#	0	0	0	3	0	3
	%	0	0	0	100	0	
Vertebrata	#	2	2	5	20	0	29
	%	7	7	14	69	0	
Totals	#	23	16	19	245	29	332
	%	7	5	6	74	9	
Total less Ostracodes	#	22	7	18	180	24	251
	%	9	3	7	72	10	

Table 12.—Summary of extant faunal zoogeographic distribution by stratigraphic unit with respect to inferred relative temperature and sea level. Data presented both with and without the ostracode fauna. See p. 21 for explanations of relative temperature factors.

Stratigraphic unit		Boreal	northern Virginian	southern Virginian	Carolinian	total	northern	southern	relative temperature TR$_1$	relative temperature TR$_2$	species richness	sea level (m)
Powells Crossroads Formation												
Sand Bridge Member												
Upper	#	20	56	66	66	80	4	5	9.1	34.5	80	+3.3 to 4.6
	%	25	70	82	82		5	6				
Lower	#	22	64	82	77	96	5	7	14.3	35.0	96	+7.9 to 9.5
	%	23	67	85	80		6	7				
Londonbridge Member	#	6	10	12	11	14	1	1	0	21.0	14	+6.7 to 7.9
	%	43	71	86	78		7	7				
Acredale Formation												
Kempsville Member												
Owl Creek loc.	#	4	4	1	0	5	3	0	−10.0	−80.0	6	−3.3?
	%	80	80	20	0		50	0				
Upper	#	34	51	53	53	71	10	3	−52.9	15.0	71	+5.5 to 6.7
	%	48	72	75	75		13	4				
Lower	#	41	97	117	117	136	8	10	16.7	34.5	136	—
(without ostracodes)	%	30	71	85	85		5	7				
(with ostracodes)	#	47	110	150	154	176						
	%	27	62	85	88							
Norfolk Member												
Upper	#	42	109	133	128	154	7	10	33.3	34.5	154	+13.7 to 15.2
(without ostracodes)	%	28	71	88	84		4	6				
(with ostracodes)	#	56	135	199	193	235						
	%	23	57	85	82							
Lower	#	22	71	92	94	108	4	10	50.0	44.0	108	—
	%	20	66	85	87		3	9				
Great Bridge Member	#	23	66	81	79	89	2	9	66.7	39.0	89	−3.0 to −1.5
	%	26	74	91	89		2	10				

%NV is the percentage of fossil species also ranging into the northern half of the Virginian Province (Northern Virginian Subprovince), which would extend from northern New Jersey to Cape Cod. The Southern Virginian Subprovince, from central New Jersey to Cape Hatteras, is the study area and, therefore, does not enter into our calculation. Because the species studied range from intertidal to littoral and sublittoral water depths of six to 12 m, they are profoundly influenced by land climates and temperatures, and consequently have broad tolerances.

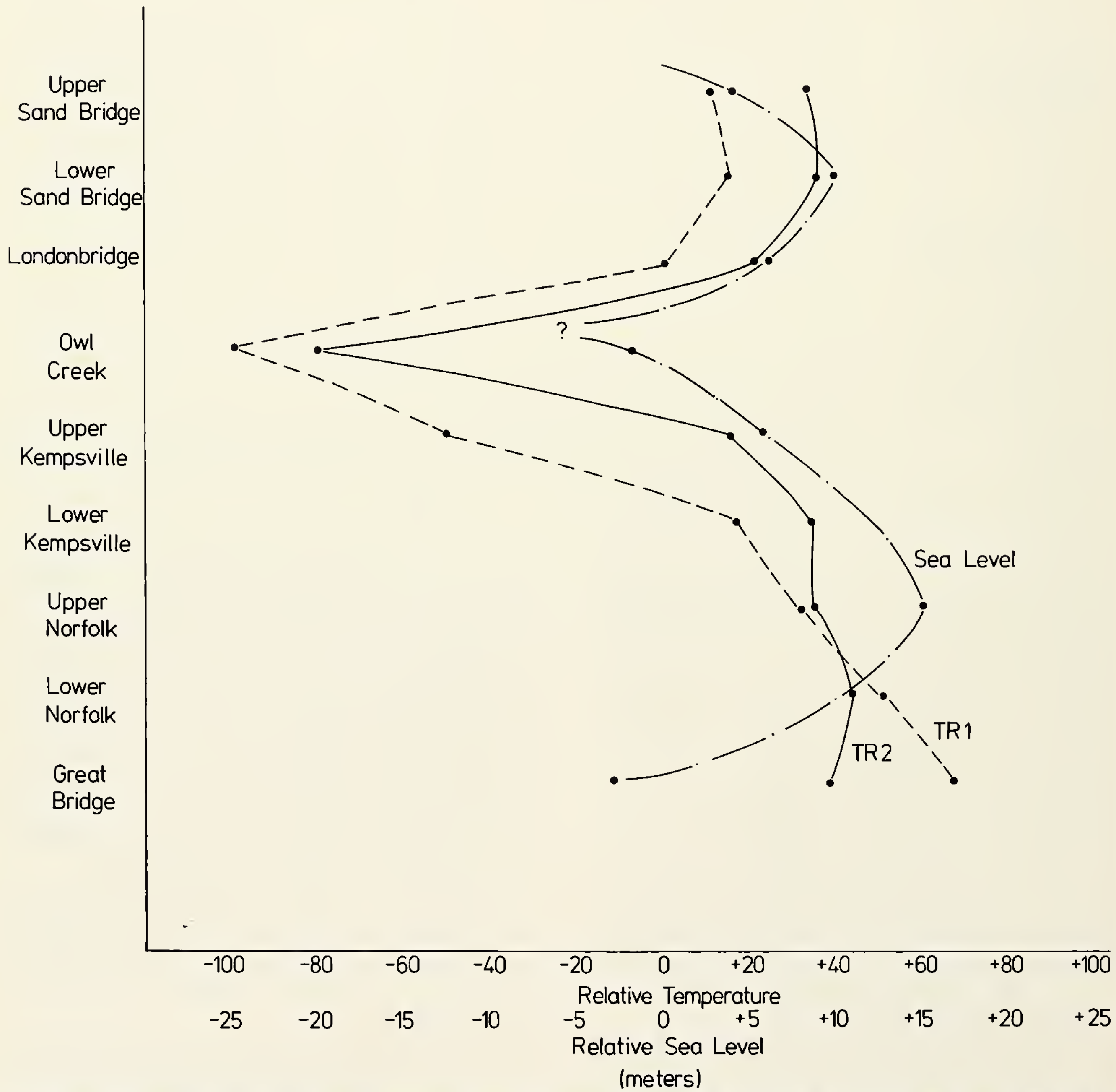
The basis for relative temperature in formula (2), therefore, is the degree of province range overlap and involves a greater number of species than formula (1). Tables 10 and 11 show the stratigraphic and taxonomic distribution of the fauna by province. Table 12 summarizes all data by stratigraphic unit and province for inferred temperature and sea level.

Using either formula, the relative temperature curves are essentially similar (Text-fig. 6). In both measures, the modern range is for sublittoral to shallow-shelf environments. *Buccinum undatum undatum* (Linné, 1758), for example, is found off Norfolk, Virginia in the deep, cold waters of the outer shelf, but is found inshore only at higher latitudes. Consequently, it is considered an exclusively northern species in this study.

By either temperature index, peak water temperature for the Acredale Formation (Text-fig. 6) was attained during the deposition of the Great Bridge Member and lower part of the Norfolk Member. Temperatures declined during the deposition of the upper part of the Norfolk Member and lower part of the Kempsville Member, and then plummeted during the deposition of the upper part of the Kempsville Member.

Beginning with the deposition of the Londonbridge Member of the Powells Crossroads Formation, sea temperatures again began to rise. This warming trend continued during deposition of the Sand Bridge Member, signaling the onset of a second transgressive–regressive event.

The relationship of inferred sea temperatures to the paleoecology of the studied fauna indicates a time-lag between changes in sea temperature and correlated changes in sea level (Text-fig. 6) with the change in sea temperature preceding changes in sea level. During the transgressive–regressive event that deposited the Acredale Formation, temperature increase led the transgressive phase, peaking before maximum sea level was attained. It again led the regressive phase of this cyclic event by starting to fall during the time elevated sea levels were depositing the upper part of the Norfolk Member. A similar situation appears to be true for a second transgressive–regressive event, which formed the Londonbridge and Sand Bridge members of the Powells Crossroads Formation. Here, maximum temperature again preceded peak transgression with the decrease in the temperature curve less pronounced than that of the Acredale Formation. Temperature curves using both formulas indicate a decline in temperature for the regressive phase. The curve generated by formula (1) is more pronounced. A reason for this discrepancy may be that the regressive Sand Bridge de-



Text-figure 6. Inferred relative sea water temperature (based on formulas TR_1 and TR_2; see text and Table 12) and relative sea level for stratigraphic units in the study area. Both temperature curves indicate a time lag between temperature and sea level changes with changes in inferred sea temperature preceding changes in sea level.

posits containing reworked material from the underlying warmer-water deposits would have had a greater bias effect upon formula (2) because formula (2) is based upon overlapping geographic ranges of many species rather than on the much smaller number of species considered exclusively northern or southern.

Sea-level estimates found in Table 12 are based upon the work of Oaks (1965), Oaks *et al.* (1974), and Cronin *et al.* (1981). However, a problem is encountered in estimating sea levels for the lower part of the Sand Bridge Member. Oaks (1965) and Oaks *et al.* (1974) estimate sea level for the Londonbridge Member at +6.7 to 7.9 m (+22 to 26 ft) ASL (above mean sea level). This is based upon the highest occurrence of their clay-silt facies of the Londonbridge Member at near +4.5 m (+15 ft) ASL in the eastern part of the Dismal Swamp. They believe these deposits to be stratigraphically equivalent to beach sands at +6.7 to 7.9 m (22 to 26 ft) ASL which are found about 32 to 42 km to the east. Oaks (1965) and Oaks *et al.* (1974) inferred a sea level elevation of +3.6 to 5.2 m (+12 to 17 ft) ASL for the lower part of the Sand Bridge Member. This estimate is based on elevations some 13 to 19 km east of those taken for the Londonbridge Member. In addition, Oaks (1965) and Oaks *et al.* (1974) place the tidal to marsh deposits of the uppermost part of the Sand Bridge Member occurring near the Suffolk Scarp at elevations of +7.6 to 8.2 m (25 to 27 ft) ASL. These regressional deposits are believed by Oaks (1965) and Oaks *et al.* (1974) to be stratigraphically equivalent to deposits occurring at +5.2 to 5.5 m (+17 to 18 ft) ASL along the west sides of the Oceana and Pungo ridges. They have invoked tilting to account for the measured elevations of this deposit near the Suffolk Scarp and a general lowering of sea level since deposition of the Londonbridge Member.

The following evidence suggests that sea level during deposition of the Sand Bridge Member was higher than Oaks (1965) and Oaks *et al.* (1974) originally thought: (1) the *in situ* fauna at locality 18b is an open-marine shelf fauna, marking a period of maximum transgression; (2) it is gradational with the underlying estuarine Londonbridge Member and overlying nearshore tidal and marsh environment deposits of the upper part of the Sand Bridge Member; and (3) the unbroken, unabraded and well-preserved shells of such commonly-occurring mollusks as *Dinocardium robustum* (Lightfoot, 1786), *Bornia longipes* (Stimpson, 1855), *Argopecten gibbus* (Linné, 1758), *Mercenaria campechiensis* (Gmelin, 1790), *Circulus liratus* (Verrill, 1882), *Epitonium multistriatum* (Say, 1826), *Prunum roscidum* (Redfield, 1860), and *Kurtziella cerina* (Kurtz and Stimpson, 1851), found at locality 18b indicate water depths ranging from about five to about 20 m for this part of the Sand Bridge Member.

Based on the preceding we have tentatively placed sea level for the lower part of the Sand Bridge Member at about +8 m ASL. This would mean that tilting would not have to be invoked to account for the high elevation of the upper part of the Sand Bridge Member. The marsh to tidal deposits occurring in the upper part of this member would have followed the retreating sea eastward toward lower elevations.

ZOOGEOGRAPHY

Valentine (1971) (see also Hazel, 1971, p. 371) found that 10 percent (eight of 80 species) of the Pleistocene ostracodes of the Norfolk Formation were Carolinian, and concluded that a separate warm-temperate province must have developed in southeastern Virginia during that time. Using Recent range data to determine apparent lethal limits, Valentine concluded that the Pleistocene seasonal variation ranged from a 20 to 22.5 degree Celsius summer maximum to a 12.5 to 15 degree winter minimum, in contrast to a Recent range of 22.5 to 25 degrees summer maximum and 5 to 7.5 degrees winter minimum.

One complication of the "lethal limits" method is the problem of incompatible ranges such as that of the typically-Boreal *Hemicythere villosa* (Sars, 1865), which Valentine (1971, p. 7) found in eight of nine Norfolk samples, but deleted from this temperature calculations. A more critical question to which the "lethal limit" method might be applied would be, "What climatic or other limitations prevented the invasion of the majority of the Carolinian species when the marine climate was supposedly so optimal?"

The mollusk data suggest a different zoogeographic interpretation for the study area. In the total Pleistocene fauna, 21 of 138 species, or 15 percent (Table 12), are presently restricted to Cape Hatteras or more southern waters (Coomans, 1962; Cerame-Vivas and Gray, 1966; Wass, 1972; Porter, 1974; Abbott, 1974; Campbell, 1976). However, within individual stratigraphic members we find a maximum of eight Carolinian species. The disparate zoogeographic conclusions drawn from ostracodes (Valentine, 1971; Hazel, 1971; Cronin, 1979) and mollusks (this study) are in good part a function of methodology and interpretation, but they might also reflect real differences between the climatic responses of the two phyletic groups. However, the addition of the ostracode distribution data (Valentine, 1971; Hazel, 1971; Cronin, 1979) to the remaining fauna (Table 12) produced a significant change only in the percentage figures of the northern Virginian column of Table 12. This change appears to be simply an artifact of the northern limit (New Jersey) of Valentine's study area. The ostracodes' climatic response therefore appears to be compatible with that of the other phyla.

The interpretation of thermal anomalies in the fossil record has been discussed by Zinsmeister (1974), based on occurrences in the Pleistocene and Recent molluscs of the California coast. He documents a number of molluscan species from Baja California, collected live up to 400 mi north of their breeding range. Their pelagic larvae are carried north by currents to become established as non-breeding outliers during milder seasons. Virginia Pleistocene specimens of *Macrocallista nimbosa* (Lightfoot, 1786), provide a good example of adventitious invasion. All specimens are juvenile, falling into two size groupings that appear to be one- and two-year growth stages. Apparently, these clams were brought north by favorable currents, settled, and grew through the first summer. Some of the hardier individuals survived through a mild winter and into the second summer before succumbing. A similar, but successful invasion of *Macrocallista maculata* (Linné, 1758) has recently colonized Bermuda (Abbott and Jensen, 1967).

Elements of the boreal Pleistocene fauna have been reported from southern Canada and New England (Clarke, Grant, and MacPherson, 1972; Richards, 1962), indicating no significant northward shift in the zoogeographic boundary at Cape Cod. Internally, however, warming waters did permit the invasion of a few Carolinian species into southeastern Virginia and the northward extension of some Southern Virginian Subprovince species as far as Long Island (Gustavson, 1972). Northern Virginian Subprovince species in turn invaded the study area during deposition of the Kempsville Member when seas were cooler.

Consequently, we conclude that the presence and relative abundance of northern and southern species are related to changes in water temperature of an interglacial sea. At no time during the deposition of the Acredale and Powells Crossroads formations was this change sufficient to change the zoogeographic equivalency of Pleistocene and Recent Virginia mollusk faunas at the provincial level.

Additional distribution data have been taken from Allison (1973), Brown and Pilsbry (1913), Conrad (1831ff, 1832, 1833, 1834, 1835), Cooke (1945), DuBar (1959, 1971), DuBar, Solliday, and Howard (1974), Hopkins, Rowland, and Patton (1972), Jordan (1974), Mansfield (1928), Palmer (1927), Richards (1947), Stanley (1972), Vĕrnburg and Vernburg (1970), and Wells (1961).

SUMMARY

Nine phyla comprising 348 species are documented and one new species is described, making the Virginia Pleistocene fauna the most thoroughly investigated along the East Coast of the United States. Detailed locality descriptions and their stratigraphic sections are given, along with an assemblage listing for each locality, as well as faunal interpretation by phylum and formational subdivision. A presence–absence, Q-mode clustering technique was employed on the data. The resulting dendrogram gave clusters of samples based upon their biofacies rather than upon any biostratigraphic component, even when the range-through method was used. The clustering of samples is in close agreement with interpreted paleoecology.

Biostratigraphic and ecostratigraphic analyses show that the Great Bridge, Norfolk, and Kempsville formations of Oaks and Coch (1973) represent basal transgressive estuarine, marine shelf, and regressive nearshore marine phases, respectively, of a single transgressive–regressive cycle of deposition. Because of the complex facies relationships that developed in such a sequence and because of intra- and interregional correlation difficulties, the above stratigraphic units have been reduced from formational status to locally significant members in this paper. The term "Acredale" is used at the formational level for the entire transgressive–regressive cycle. This permits direct correlation and continuity with established literature, recognition of detailed local stratigraphy, and assignment to "undifferentiated Acredale" when the proper subunit cannot be established. By the same token, the Londonbridge–Sand Bridge units which are part of a second transgressive–regressive event are recognized as formal subdivisions, of member status, within the Powells Crossroads Formation.

The fauna of the Acredale Formation shows a transitional-upward change of paleoenvironments from cooler-water, estuarine conditions, as expressed by the Great Bridge faunal assemblage toward a warmer-water, open-marine environment. The beginning of a cooling event takes place during the time of maximum transgression, forming the upper part of the Norfolk Member and its contained fauna. Tracing the Norfolk fauna westward, the warm, open-marine conditions gradually change toward colder, brackish water. It is thought that this lateral temperature gradient is not due simply to the effect of shoaling on the range of seasonal temperature fluctuations. Rather, it is thought that the lateral temperature change was glacially induced, causing increasingly cool-water conditions with time. This implies that isotherms and isochrons are coincident, and illustrates the time-transgressive nature of the Norfolk sediments. This also shows that there is a time lag between peak sea temperature and maximum transgression. Such a time lag would be consistent with the presence of cold-water faunas in the overlying Kempsville +5.8 m (+19 ft) ASL stillstand that developed during the late Acredale regression.

A second transgressive–regressive cycle is contained in the unconformably-overlying Powells Crossroads Formation. Here the basal unit, the Londonbridge Member, contains an estuarine assemblage that develops into an open marine, warmer-water fauna in the lower part of the overlying Sand Bridge Member. The marine shelf assemblage from this part of the Sand Bridge has a range of overlapping water depths of about six to 14 m, implying a sea level elevation greater than that postulated by Oaks and Coch (1973). Traced upward, the Sand Bridge fauna, like that of the Kempsville, develops cold-water aspects and shallow-marine conditions in the final regressive phase.

Comparing the implied sea temperatures of the two cycles, it appears that sediments from the Powells Crossroads Formation were deposited in water colder than that for the underlying Acredale Formation.

SYSTEMATIC PALEONTOLOGY

INTRODUCTION

The Pleistocene fauna of southeastern Virginia is essentially modern in character (97 percent of the species are extant). Many of the molluscan species are well described by Abbott (1954, 1974) and their redescription here is considered unnecessary. Consequently, a diagnosis only is given. Molluscan species either not described by Abbott (1954, 1974) or those requiring further definition are briefly described. The bryozoans are described in detail because no single comprehensive and readily-obtainable source is available to the reader. The intent is to make this important faunal component more readily identifiable to other investigators of the Pleistocene. Bryozoan classification follows that of Cheetham and Sandberg (1964) and Cook (1968a, 1968b), while that for the mollusks follows Keen (1971).

Abbott (1954) did not follow the ICZN Code (1961, sect. XI, Art. 51d, p. 51) which states, "If a species-group taxon was described in a given genus and later transferred to another, the name of the author of the species group name, if cited, is to be enclosed in parentheses," but rather (Abbott, 1954, p. 86) stated, "Modern workers are attempting to abandon this useless frill of nomenclature, and in this book they [parentheses] are not used." He later recanted (Abbott, 1974, pp. 7, 8), following the Code.

In the discussion of the species, observations on occurrence and significance within the Virginia fauna are made where pertinent. Life habits of many of the bivalves have been discussed by Stanley (1970), and Castagna and Chanley (1973). These data have been used in some discussions, but the reader should consult the original references for further detail. Comparisons are frequently made with related species, both Tertiary and Recent, especially with species of the Virginia Neogene, because a knowledge of Pliocene species is necessary to appreciate the evolution of Pleistocene and Recent species and assemblages. In addition, the Yorktown Pliocene immediately underlies Pleistocene deposits around and to the west of the Dismal Swamp, so spoil material in that area frequently contains mixed Plio-Pleistocene assemblages, making a knowledge of both faunas necessary in order to attain an accurate interpretation of the area.

Geographic distribution is given by state, and "Massachusetts to Florida" means that these states contain the northern and southern limits of a species, but does not necessarily mean that the species has been recorded continuously through this range. Distributional data on the mollusks has come largely from Abbott (1954, 1968, 1974), Dall (1892, 1903), Maury (1920, 1922), Richards (1962) and Wass (1972), that on the bryozoans from Maturo (1968) as well as other numerous publications that deal with bryozoans or other faunal groups. These are cited in the systematics.

Most illustrated specimens are stored at the United States National Museum of Natural History and filed under the numbers, USNM 218151–218303. Two illustrated specimens, *Nucula major* Richards, 1944, and *Epitonium championi* Clench and Turner, 1952, are stored at the Academy of Natural Sciences, Philadelphia (ANSP), under catalogue numbers 64321 and 64322, respectively. The repository and catalogue number of other specimens are listed where known.

Measurements of the bryozoan and micro-molluscan material were made with an optical micrometer. A vernier caliper was used to obtain the measurements for the remaining molluscan material.

The following terms are used to describe the mollusk taxa: minute—less than four mm; very small—five to 10 mm; small—11 to 25 mm; moderate—26 to 50 mm; large—51 to 100 mm; and very large—greater than 100 mm.

ACRONYMS OF REPOSITORY INSTITUTIONS

AMNH: American Museum of Natural History, New York, NY, U.S.A.

ANSP: Academy of Natural Sciences, Philadelphia, PA, U.S.A.

$ANSP_p$: Academy of Natural Sciences, Philadelphia, PA, U.S.A. (Paleontology)

BMNH: British Museum (Natural History), London, England, U.K.

LS: Linnaean Society of London, London, England, U.K.

MCZ: Museum of Comparative Zoology, Cambridge, MA, U.S.A.

MUM: Manchester University Museum, Manchester, England, U.K.
PRI: Paleontological Research Institution, Ithaca, NY, U.S.A.
RAMM: Royal Albert Memorial Museum, Exeter, Devon, England, U.K.
USNM: United States National Museum of Natural History, Washington, DC, U.S.A.
YPM: Yale Peabody Museum, New Haven, CT, U.S.A.

Phylum **BRYOZOA** Ehrenberg, 1831

Order **CHEILOSTOMATA** Busk, 1852

Family **MEMBRANIPORIDAE** Busk, 1854

Genus **MEMBRANIPORA** Blainville, 1830

Membranipora tenuis Desor, 1848
Plate 1, figures 1, 4

Membranipora tenuis Desor, 1848, p. 66.
Membranipora tenuis Desor. Cook, 1968a, p. 127, pl. 2, fig. B, text-fig. 4.

Description.—Zoarium encrusting, unilamellar or multilamellar; zooecia elongate, rectangular to hexagonal; cryptocyst denticulate, granular, usually well-developed proximally, often asymmetrical, distally narrow rim around opesium; mural rim beaded, separated from adjacent zooecia by thin line; tubercles often present.

Diagnosis.—Zooecia have an asymmetrical, well-developed proximal cryptocyst, a pair of lateral denticles larger than the others, and a beaded mural rim.

Measurements (in mm).—

	length of zooid	*width of zooid*	*length of primary orifice including sinus*	*width of primary orifice*
USNM 218151				
Number of Measurements	20	20	20	20
Mean	0.424	0.274	0.246	0.192
Standard Deviation	0.057	0.037	0.026	0.024
Range	0.27–0.50	0.22–0.34	0.20–0.29	0.13–0.23

Distribution.—Miocene: Florida, Jamaica; Pleistocene: Virginia; Recent: cosmopolitan, Atlantic and Pacific oceans, Gulf of Mexico, Caribbean Sea; shallow water (less than 31 m), reduced salinities to normal marine.

Occurrence in this study.—Localities 17c, 17d, 17e, 17f, 18b, 18d, 18e, 20a, 20b, 21a, 22a, 22b, 22c, 25a.

Type information.—Holotype unknown. Figured hypotype: USNM 218151.

Discussion.—Considerable variation occurs in this species as noted by Shier (1964) and illustrated by Osburn (1940). Cook (1968a, p. 128) studied in detail *M. tenuis* and related species. She states that depending on the amount of proximal cryptocyst and the development of the denticles, zooids of the same colony may be indistinguishable from *M. arborescens* Canu and Bassler, 1928, and *M. savarti* Audouin, 1826, but that usually *M. tenuis* has an asymmetrical, well-developed proximal cryptocyst and a pair of lateral denticles longer than the others.

Family **ELECTRIDAE** Lagaaij, 1952

Genus **ELECTRA** Lamouroux, 1816

Electra monostachys (Busk, 1854)
Plate 1, figure 2

Membranipora monostachys Busk, 1854, p. 61, pl. 70, figs. 1–4.
Electra monostachys (Busk). Canu and Bassler, 1923, p. 17, *partim*, pl. 29, figs. 2, 3, *non* fig. 1.
Electra hastingsae Marcus, 1938, p. 17, pl. 2, fig. 7.
Electra monostachys (Busk). Lagaaij, 1963, p. 168, pl. 1, fig. 1.

Description.—Zoarium encrusting; zooecia elongate, smooth-surfaced; proximal gymnocystal portion narrower, extending one-fourth to one-half of the zooecial length; opesium elliptical to oval; mural rim raised with seven to 10 pairs of spines arched over opesia; spines arranged with one distolateral (erect to semierect) pair somewhat thicker than the six to nine pairs of incurved lateral spines and with one stout, thick median proximal spine. Periancestrular budding lateral to distolateral. Basal wall of zooid etched into calcareous substrate.

Diagnosis.—Elongate zooecia with a raised mural rim. The mural rim has a thick median proximal spine with either paired, arched distolateral spines, or seven to 10 pairs of spines arched over the opesia with distolateral pair thicker.

Measurements (in mm).—

	length of zooid	*width of zooid*	*length of primary orifice including sinus*	*width of primary orifice*
USNM 218152				
Number of Measurements	20	20	20	20
Mean	0.404	0.252	0.292	0.167
Standard Deviation	0.508	0.044	0.059	0.033
Range	0.32–0.50	0.16–0.32	0.20–0.41	0.10–0.22

Distribution.—Pliocene: South Carolina; Pleistocene: California, Texas, Maryland, Virginia; Recent: Bay of Fundy to Brazil, Balboa (Panama), two to 19 fathoms in waters of low to normal salinity.

Occurrence in this study.—Localities 17c, 17d, 17e, 17f, 18e, 19a, 20a, 20b, 22a, 22b, 22c, 25a.

Type information.—Holotype unknown. Figured hypotype: USNM 218152. Dr. Patricia Cook states (written commun., 1983) that a lectotype has never been formally indicated but may be regarded as BMNH, Britain, 1899.7.1.1089; (see Ryland, 1969).

Discussion.—Powell and Crowell (1967, p. 339) note that this species occurs in the Bay of Fundy region as two distinct forms that do not appear to intergrade. The first, referred to as the "3-spine form" has paired distal lateral spines and one robust, proximal median spine. The second, referred to as the "multispinous form" has 12 to 20 spines around the opesia. All Virginia specimens are of the multispinous form. The periancestrular budding is very similar to that illustrated by Cook (1964, p. 394, fig. 1).

Family **CUPULADRIIDAE** Lagaaij, 1952

Genus **CUPULADRIA** Canu and Bassler, 1919

Cupuladria biporosa Canu and Bassler, 1923
Plate 1, figure 5; Plate 2, figure 7

Cupuladria biporosa Canu and Bassler, 1923, p. 29, pl. 47, figs. 1, 2.
Cupuladria biporosa (Canu and Bassler). Cook, 1965b, p. 203, pl. 1, figs. 2A, B, 3A, B, 4A, B, 5, 6A, B, text-figs. 1g–j.
Cupuladria biporosa (Canu and Bassler). Scolaro, 1970, p. 96, text-fig. 1.

Description.—Zoarium discoidal to saucer-shaped; zooecia subrhombic to elongate hexagonal or octagonal, quincunx pattern; mural rim distinct; cryptocyst granular, narrow distally, wide laterally and proximally, descending gently laterally and often proximally forming salient shelf; opesia irregular, usually somewhat oval or rounded rectangular; vibraculum auriform, situated distal to each zooecium; basal surface divided into regular concentric series of small nearly square sectors with two to six pores.

Diagnosis.—Basal surface divided into a concentric series of nearly square sectors, each with two to six pores. Opesia nearly straight-sided, one kind of ordinary vibracula, and auriform vicarious vibracula.

Measurements (in mm).—

	length of zooid	*width of zooid*	*length of primary orifice including sinus*	*width of primary orifice*	*length of avicularium*	*width of avicularium*
USNM 218153						
Number of Measurements	20	20	20	20	20	20
Mean	0.346	0.246	0.285	0.160	0.163	0.135
Standard Deviation	0.030	0.021	0.041	0.016	0.015	0.016
Range	0.29–0.38	0.21–0.31	0.20–0.35	0.12–0.18	0.14–0.20	0.11–0.17

Distribution.—Miocene: Texas, Louisiana, Mississippi, Alabama, Florida, Jamaica, Dominican Republic, Costa Rica; Pliocene: Louisiana, Florida, Argentina, Panama; Pleistocene: Louisiana, Virginia; Recent: California to Galapagos Is., Brazil, Colombia, West Indies, Gulf of Mexico, S.W. Mediterranean, Spain, Portugal, Canary Is., Madeira Is., Cape Verde Is., Senegal, Gulf of Guinea, Bay of Biafra.

Occurrence in this study.—Localities 17d, 17e, 18c, 18d, 19a, 20a, 22b.

Type information.—Holotype: USNM 68425. Figured hypotype: USNM 218153.

Discussion.—Cook (1965b, pp. 197–209) discusses in detail the differences between *C. biporosa* and *C. canariensis* (Busk, 1859). The former has the basal surface divided into a concentric series of square sectors, each of which contains two to six pores while the latter possesses an irregular series of long rectangular sectors with six to 12 pores, interspersed with short wide sectors containing three to six pores. In addition, *C. biporosa* has the opesia almost straight-sided, a gently descending cryptocyst, one kind of ordinary vibracula, and auriform vicarious vibracula. The specimens described and illustrated by Scolaro (1970, p. 96) from the Miocene Red Bay Formation differ from the Virginia Pleistocene specimen in the shape of the opesia, and the narrower, more steeply-descending cryptocyst. Only fragments of *C. biporosa* were found at the previously-mentioned localities and none have vicarious vibracula.

Cupuladria owenii (Gray, 1828)
Plate 1, figure 6; Plate 3, figure 6

Lunulites owenii Gray, 1828, p. 8, pl. 3, figs. 15, a, b.
Cupuladria owenii (Gray). Busk, 1854, p. 99, pl. 115, figs. 1–5.
Cupuladria owenii (Gray). Cook, 1965b, p. 213, pl. 2, figs. 3A, B, text-fig. 2c.

Description.—Zoarium saucer- to bowl-shaped; basal surface smooth to finely tuberculate, radially grooved; zooecia small, narrow, rhomboidal, radial to quincunx pattern; vestibular arch incurved, convergent with distinct distal denticles; lateral cryptocyst granular, descending to four to six wide to narrow, irregularly-shaped denticles; vibraculum interzooecial, nondenticulate, auriform, situated at distal end of zooecia.

Diagnosis.—Basal surface radially grooved. Lateral cryptocyst granular with four to six irregularly-shaped denticles. Vibraculum nondenticulate, auriform, at distal end of zooecia.

Measurements (in mm).—

	length of zooid	*width of zooid*	*length of primary orifice including sinus*	*width of primary orifice*	*length of avicularium*	*width of avicularium*
USNM 218154						
Number of Measurements	20	20	20	20	20	20
Mean	0.287	0.253	0.207	0.110	0.139	0.130
Standard Deviation	0.042	0.051	0.204	0.034	0.011	0.011
Range	0.23–0.37	0.17–0.37	0.17–0.25	0.06–0.20	0.11–0.16	0.10–0.15

Distribution.—Miocene: Florida, Maryland; Pliocene: Florida, Virginia, South Carolina; Pleistocene: Virginia; Recent: Canary Islands to Bay of Biafra, South Africa.

Occurrence in this study.—Localities 17d, 17e, 18b, 18d, 22b.

Type information.—Lectotype: BMNH, West Coast of Africa, 1899.7.1.4879. Figured hypotype: USNM 218154.

Genus **DISCOPORELLA** d'Orbigny, 1851

Discoporella umbellata depressa (Conrad, 1841)
Plate 1, figure 7; Plate 3, figure 7

Lunulites depressa Conrad, 1841, p. 348.
Discoporella umbellata depressa (Conrad). Cook, 1965a, p. 180, pl. 3, figs. 2, 4.

Description.—Zoarium free, cup- to saucer-shaped; basal surface with tubercles and radial grooves occasionally pitted; zooecia narrow, regularly-arranged, rhomboidal with large interzooecial, non-denticulate, auriform vibraculum at distal end; lateral cryptocyst granular, descending steeply, horizontal part frequently perforate; opesia large, semicircular, curved or slightly sinuate, proximally nondenticulate; opesiules large, irregular to rounded, four to nine in number.

Diagnosis.—Narrow zooecia with large, rounded, nondenticulate opesia that have a curved proximal edge. Opesiules are large, rounded, four to nine in number, with narrow bars between them. Vibracular opesiae are smaller and nondenticulate.

Measurements (in mm).—

	length of zooid	*width of zooid*	*length of primary orifice including sinus*	*width of primary orifice*	*length of avicularium*	*width of avicularium*
USNM 218155						
Number of Measurements	20	20	20	20	20	20
Mean	0.332	0.300	0.102	0.136	0.122	0.098
Standard Deviation	0.029	0.045	0.012	0.007	0.009	0.006
Range	0.29–0.43	0.23–0.38	0.08–0.13	0.13–0.15	0.11–0.14	0.09–0.11

Distribution.—Miocene: Dominican Republic, Jamaica, Patagonia, Florida, Louisiana; Pliocene: Florida, South Carolina, North Carolina; Pleistocene: California, Virginia; Recent: North Carolina to Straits of Florida, Gulf of Mexico, Caribbean, Brazil, California to Ecuador, Hawaii, Galapagos at depths ranging from seven to 2723 fathoms.

Occurrence in this study.—Localities 17d, 17e, 18b, 18c, 18d, 18e, 19a, 20a, 21a, 22b.

Type information.—Holotype: unknown. Figured hypotype: USNM 218155.

Discussion.—Cook (1965a), in her work on the Cupuladriidae, found consistent character differences in the *D. umbellata* complex between European and American fossil and Recent material, and consequently, placed all American records in *D. umbellata depressa.* The American material according to Cook (1965a, p. 176) is characterized by

> ... narrow zooecia, nondenticulate opesiae, with curved proximal edge, the relatively small size of the vibracular opesia, which is never denticulate, and the smaller number of large opesiules.

The material described by Scolaro (1970) from the Miocene of northwestern Florida differs little from that found in the Virginia Pleistocene, the only notable differences being narrower zooecia and a more steeply-descending lateral cryptocyst for the Pleistocene specimens.

Family **CRIBRILINIDAE** Hincks, 1880

Genus **CRIBRILINA** Gray, 1848

Cribrilina punctata (Hassall, 1841)
Plate 1, figures 3, 8

Lepralia punctata Hassall, 1841, p. 368, pl. 9, fig. 7.
Cribrilina punctata (Hassall). Gray, 1848, p. 117.
Cribrilina punctata (Hassall). Ryland and Stebbing, 1971, p. 68, fig. 1B.

Description.—Zoarium encrusting; zooecia small, ovoid to subpolygonal; frontal convex, five to six pairs of usually ill-defined costae somewhat radially arranged; small pseudopore on tubercle near base of each costa, occasionally more medial pseudopores also present; costae separated by three to five intercostal lacunae; lacunae round to irregular, outermost somewhat arch-shaped; orifice semielliptical to subquadrate; proximal part of orifice nearly straight apertural bar formed from distalmost costae, medially produced as a mucro; three to four spines represented by spine bases distal to orifice, proximalmost persist in presence of ovicell; avicularia small, acuminate, usually on both sides of apertural bar, distal part raised, directed distally or distolaterally; ovicell globose to somewhat elongate, smooth, perforated by a small number of pseudopores.

Diagnosis.—Frontal with five to six pairs of poorly-defined, somewhat radially-arranged costae with a pseudopore on a tubercle near the base of each costa. Proximal part of orifice is a bar with a central mucro while three to four spine bases occur distal to orifice. Ovicell smooth, and perforated by a small number of pseudopores.

Measurements (in mm).—

	length of zooid	*width of zooid*	*length of primary orifice including sinus*	*width of primary orifice*	*length of avicularium*	*width of avicularium*	*length of ovicell*	*width of ovicell*
USNM 218156								
Number of Measurements	20	20	20	20	20	20	10	10
Mean	0.478	0.260	0.092	0.122	0.065	0.039	0.194	0.200
Standard Deviation	0.112	0.030	0.012	0.016	0.016	0.013	0.021	0.017
Range	0.35–0.62	0.20–0.31	0.07–0.12	0.09–0.15	0.03–0.09	0.02–0.06	0.15–0.23	0.17–0.23

Distribution.—Miocene: Maryland; Pleistocene: Virginia; Recent: Baffin Bay to Massachusetts, extensive north and south of Cape Hatteras (Maturo, 1968, p. 276).

Occurrence in this study.—Localities 17d, 22a.

Type information.—Neotype: BMNH 1911.10.1.-679a. Figured hypotype: USNM 218156.

Discussion.—The tuberculate ovicell with or without a median avicularium, reported by Ryland and Stebbing (1971, p. 68) as sometimes being present, was not observed on the Virginia material. The specimens shown in Plate 1, figure 3, showing lacunae that are irregular in size and variable in number, are similar to those illustrated by Canu and Bassler (1923, p. 87, pl. 15, fig. 11) and Osburn (1912, p. 232, pl. 24, figs. 41, 41a, 41b). Those shown in Plate 1, figure 8, are very similar to that illustrated by Ryland and Stebbing (1971, p. 68, fig. 1B), Rogick and Croasdale (1949, pl. 4, figs. 24, 25), and Osburn (1933, pl. 8, figs. 5, 6). This species is very similar to *C. cryptooecium* Norman, 1903. Ryland and Stebbing (1971, p. 69) discuss in detail the differences between *Cribrilina punctata* and *C. cryptooecium* and state that the most obvious differences are the non-punctate ovicell bearing a V- or Y-shaped ridge and the large amount of secondary calcification in the latter species.

Prenant and Bobbin (1966, p. 581) give a detailed synonymy and description of *C. punctata.*

This species was originally regarded in North America as a cold-water form having a southern geographical limit of Massachusetts, however, Maturo (1968) reports this species ranging extensively north and south of Cape Hatteras.

It should be noted that the figure legends given by Ryland and Stebbing (1971, p. 66) for *C. punctata* and *Membraniporella nitida* (Johnston, 1838) appear reversed so that figure 2B is actually *M. nitida.*

Although *C. punctata* is placed by the authors in the Southern Virginian Subprovince (eurythermal) because of its extensive range, it should be noted that *C. punctata* is a faunal dominant in New England waters where it reproduces both summer and winter (Abbott, 1975).

Genus **MEMBRANIPORELLA** Smitt, 1873

Membraniporella cf. **Membraniporella petasus**
Canu and Bassler, 1928
Plate 1, figure 9

Membraniporella petasus Canu and Bassler, 1928, pp. 36–37, pl. 4, figs. 1–2.

Description.—Zoarium encrusting; zooecia distinct, elongate, elliptical; frontal highly convex with nine to 11 broad, flat costules separated by elongate subtriangular lacunae near sides and small irregular to subtriangular lacunae near middle; aperture rounded to semielliptical, concave proximally due to proximal deflection of distalmost costae; "... the peristome bears three to four short palmate bifid spines, of which the two lateral ones are wide and in the form of a bifid tongue" (Canu and Bassler, 1928, p. 36).

Diagnosis.—Elongate zooecia with nine to 12 flat costules separated by subtrigonal lacunae. Lacunae become smaller near the middle. Proximal point of orifice is a bar with a central proximal deflection, while three to four spine bases occur distal to orifice. Spine bases bear palmate bifid spines.

Measurements (in mm).—

	length of zooecia	*width of zooecia*	*length of primary orifice including sinus*	*width of primary orifice*
USNM 218157				
Number of Measurements	20	20	20	20
Mean	0.448	0.295	0.133	0.147
Standard Deviation	0.049	0.049	0.032	0.019
Range	0.35–0.50	0.25–0.40	0.11–0.17	0.12–0.17

Distribution.—Pleistocene: Virginia; Recent: Caribbean, two to 23 fathoms (Osburn, 1940, p. 404), 143 and 201 fathoms (Canu and Bassler, 1928, p. 37).

Occurrence in this study.—Localities 17c, 17d, 18d, 20b.

Type information.—Syntypes: USNM 7550, 7551. Figured hypotype: USNM 218157.

Discussion.—The Virginia specimens are similar to those described and illustrated by Canu and Bassler (1928), but the branched oral spines are not preserved, leaving only the spine bases. The pattern of fusion of the costae appears to be variable in the Virginia specimens. Some individuals within the same colony have small branched costae, so that the lacunae are elongate and teardrop to subtrigonal in shape, reaching almost to the midline of the zooid, thereby reducing to a minimum the central region, which would normally have the small, irregular lacunae. At the other extreme, branching begins very near the sides of the zooid so that most of the frontal possesses small, irregular to subtrigonal lacunae.

Family **HIPPOPORINIDAE** Bassler, 1935

Genus **HIPPOPORINA** Neviani, 1895

Hippoporina porosa (Verrill, 1879)
Plate 2, figure 6

Escharella pertusa? (Esper). Verrill, 1875b, p. 143.
Escharina porosa Verrill, 1879, p. 193 (*fide* Maturo and Schopf, 1968, p. 48).
Hippoporina porosa (Verrill). Maturo and Schopf, 1968, p. 48, fig. 12A.

Description.—Zoarium encrusting; zooecia elongate polygonal to rectangular; separated from adjacent zooids by distinct thin wall; frontal convex with large tremopores separated by ridges, tubercles at intersection of ridges; orifice large, round with broad shallow sinus and well-developed condyles; raised beaded rim surrounding lateral and proximal sides of orifice with mucro sometimes present proximally; ovicell large, globose, surface sharply granulated, perforated by numerous small round pores; lateral walls commonly with five communication pores in upper row and seven in lower row; distal wall with 10 to 13 communication pores along basal and lateral margins.

Diagnosis.—Frontal has large pores bounded by ridges that have tubercles at their intersection. Orifice with a beaded rim along lateral and proximal sides. Lateral wall with five communication pores in upper row and seven in lower row, while distal wall has 10 to 13 pores.

Measurements (in mm).—

	length of zooid	*width of zooid*	*length of primary orifice including sinus*	*width of primary orifice*	*length of ovicell*	*width of ovicell*
USNM 218162						
Number of Measurements	20	20	20	20	10	10
Mean	0.512	0.327	0.124	0.142	0.252	0.337
Standard Deviation	0.089	0.044	0.020	0.009	0.289	0.223
Range	0.40–0.72	0.23–0.42	0.07–0.25	0.12–0.15	0.20–0.32	0.28–0.37

Distribution.—Pleistocene: Virginia; Recent: Maine, New York, Massachusetts. Maturo (1968, p. 276) reports this species to range extensively north and south of Cape Hatteras.

Occurrence in this study.—Localities 17d, 17e, 20b, 22b.

Type information.—Lectotype: YPM 2902. Paralectotypes: USNM 4811, YPM 2903A. Figured hypotype:

USNM 218162.

Discussion.—Maturo and Schopf (1968, p. 49) state that "*Escharina porosa* was erected by Verrill in 1879 for the material he obtained in 1874 and described in 1875 as being possibly representative of *Escharella pertusa* (Esper). The lectotypes and paralectotypes were collected in 1874 and carry the names '*Escharella pertusa*' and '*Esch. pertusa*', respectively, in Verrill's handwriting." Maturo and Schopf (1968), upon examination of Verrill's 1874 material, found that he included two distinct species under the name of *Escharella pertusa*? as well as in his later description of *Escharina porosa* (Smitt, 1873). Maturo and Schopf (1968, p. 49) designated the lectotype and paralectotypes of *Escharina porosa* for the larger specimens, and erected a new species, *Hippoporina verrilli* (Maturo and Schopf, 1968) to include the smaller material. Considerable confusion has arisen over the species *porosa* because most authors following Osburn (1912) have placed it in synonymy with *Cellepora pertusa* Esper, 1796. Maturo and Schopf (1968, p. 50) state that *porosa* should be placed within the genus *Hippoporina* and discuss five different concepts of the species *pertusa*, none of which matches that of *E. porosa* Verrill.

Abbott (1971), who conducted a very detailed study of *H. porosa* as well as other related species from Block Island Sound, states (p. 99) that the primary difference between *H. porosa* and *H. pertusa* from western Europe is that the ovicell of the European specimens is flatter and has a "... smooth regular, unperforated lateral rim called an 'ectooecium' by some writers."

Hippoporina cf. **H. verrilli**
Maturo and Schopf, 1968
Plate 3, figure 1

Escharella pertusa? (Esper). Verrill, 1875b, p. 41 (part).
Lepralia pertusa (Esper). Osburn, 1912, p. 241 (part), pl. 26, figs. 56a, b, c.
Hippoporina verrilli Maturo and Schopf, 1968, p. 54, figs. 12B, C.
Hippoporina cf. *H. verrilli* Maturo and Schopf. Abbott, 1971, p. 114, fig. 24, pl. 6.

Description.—Zoarium encrusting; zooecia quadrangular to hexagonal, separated by thin raised wall; frontal tremocyst perforated by 20 to 40 evenly-spaced pores; orifice round to somewhat quadrate with a very shallow, broad, arcuate sinus proximal to weakly-developed denticles; collar thin, prominent, outward-flaring, trilobate, situated on lateral and proximal sides of orifice, usually of near equal development, often best developed laterally, but best developed proximally when umbo is present; ovicells large, globose, slightly appressed, surface rough and knobby, perforated by 20 to 40 small pores; avicularia rare, small, broadly acute, directed proximolateral or lateral; lateral walls with four to five communication pores in upper row, four in lower row; distal wall with five to eight communication pores.

Diagnosis.—Frontal perforated by only 20 to 40 evenly-spaced pores. Orificial collar is thin, prominent, outward-flaring and trilobate. Lateral walls with four to five communication pores in upper row and four pores in the lower row, while distal wall has five to eight such pores.

Measurements (in mm).—

	length of zooid	*width of zooid*	*length of primary orifice including sinus*	*width of primary orifice*	*length of ovicell*	*width of ovicell*
USNM 218163						
Number of Measurements	20	20	20	20	5	5
Mean	0.421	0.255	0.109	0.120	0.186	0.240
Standard Deviation	0.057	0.036	0.015	0.010	0.016	0.020
Range	0.35–0.55	0.20–0.35	0.09–0.14	0.10–0.13	0.16–0.20	0.21–0.28

Distribution.—Pleistocene: Virginia; Recent: Cape Cod to Gulf of Mexico.

Occurrence in this study.—Localities 18d, 20b.

Type information.—Holotype: USNM 11920. Paratypes: USNM 11921, 11922, 11923, 11924, 11925; YPM 2903B. Figured hypotype: USNM 218163.

Discussion.—*H. verrilli* is distinguished from *H. porosa* by its smaller size, lower number of frontal pores, presence of a trilobate orificial collar, delicate condyles, and smaller number of communication pores on the lateral and distal wall. This species, according to Maturo and Schopf (1968, p. 57), differs from *H. acuta* Cook, 1964, in that the latter species has communication pores about one-third of the way up the distal wall and has pointed avicularia of medium width, directed proximomedially, and from *H. lacrimosa* Cook, 1964, in that this species has broad, spatulate avicularia directed proximally.

The specimens observed from the Pleistocene of Virginia differ from those described by Maturo and Schopf (1968, p. 54) in the scarcity of avicularia, the smaller and more numerous ovicell pores, and in the development of the orificial collar. The specimens, in these characteristics, are in closer agreement to those described by Abbott (1971, p. 114) as *Hippoporina* cf. *H. verrilli*. It should be noted that the avicularia described by us as broadly acute are not well preserved.

Although this species is placed by us in the Southern Virginia Subprovince (eurythermal) because of its extensive range, it should be noted that *H.* cf. *H. verrilli* is dominant in New England waters, where it reproduces both summer and winter (Abbott, 1975). It should also be noted that Abbott (1975, p. 40) questions the geographic range of this species.

Family **SCHIZOPORELLIDAE** Jullien, 1903

Genus **SCHIZOPORELLA** Hincks, 1877

Schizoporella errata (Waters, 1878)
Plate 2, figures 1, 3–5

Lepralia errata Waters, 1878, p. 11, pl. 1, fig. 9.
Schizoporella errata (Waters). Ryland, 1965, p. 64, text-figs. 31a, b.
Schizoporella errata (Waters). Hastings, 1968, p. 356.
Schizoporella errata (Waters). Ryland, 1968, fig. 3c.
Schizoporella errata (Waters). Powell, 1970, p. 1848.

Description.—Zoarium encrusting, adventitious layers randomly oriented; zooecia hexagonal to quadrangular; frontal flat to slightly convex, perforated by a smaller number of large pores situated in pits or depressions and surrounded by thickened ridges; sometimes small umbo developed proximal to orifice; orifice usually semicircular, often situated to one side of the midline; sinus usually wide, shallow with a small denticle at each corner of the proximal lip; oral avicularia single, sometimes paired, acuminate, rostra elongate, occasionally raised, situated proximolaterally, directed outward at wide angle; larger oral avicularia also present, rostra elongate; ovicell globose, perforate, proximal cusps sometimes extended and almost encircling orifice.

Diagnosis.—Zooecia hexagonal to quadrangular with a nearly flat frontal perforated by a few large pores situated in depressions that are surrounded by thickened ridges. Avicularia of two sizes with each having an elongate rostrum.

Measurements (in mm).—

	length of zooid	*width of zooid*	*length of primary orifice including sinus*	*width of primary sinus*	*length of oral avicularia*	*width of oral avicularia*	*length of frontal avicularia*	*width of frontal avicularia*	*length of ovicell*	*width of ovicell*
USNM 218158–218160										
Number of Measurements	20	20	20	20	20	20	20	20	10	10
Mean	0.621	0.318	0.126	0.135	0.115	0.069	0.180	0.115	0.257	0.275
Standard Deviation	0.115	0.079	0.013	0.011	0.014	0.013	0.027	0.023	0.019	0.021
Range	0.45–0.80	0.23–0.48	0.10–0.16	0.10–0.15	0.09–0.13	0.05–0.09	0.14–0.23	0.08–0.16	0.23–0.28	0.25–0.30

Distribution.—Because of the confusion with respect to the proper identification of *S. errata* and *S. unicornis* (Johnston, 1847), geologic and geographic distributions are in doubt. Hastings (1968, p. 356) notes that specimens originally reported as *S. unicornis* from Beaufort, North Carolina, western Florida, Panama and Brazil belong to *S. errata*. A similar conclusion was reached by Powell (1970) for seven records of *S. unicornis* occurring between Cape Cod, Massachusetts and Chesapeake Bay, Virginia.

Occurrence in this study.—Localities 17b, 17c, 17d, 17e, 17f, 18a, 18b, 18d, 19a, 20a, 20b, 21a, 22a, 22b, 22c, 25a.

Type information.—Lectotype: MUM H.1186, Waters Collection. Figured hypotypes: USNM 218158, 218159, 218160.

Discussion.—The most consistent distinguishing characters for this species as found in the Virginia Pleistocene are: 1) the large pores situated in pits or depressions and surrounded by thickened ridges; and 2) the large avicularia with elongate rostra situated near the level of the sinus and usually directed outward at a wide angle. Considerably more variation seems to exist in the Virginia material than that previously reported for this species. The orifice, although usually round with a broad shallow sinus, can develop toward one that is transversely arcuate with a narrower sinus.

There is also a difference in the position of the larger avicularia, which Powell (1970) described as being frontal, and which Hastings (1968, p. 358) describes as "... not situated in relation to a particular zooecium ...." In the Virginia material, these larger avicularia are commonly found to occupy an oral position similar to that of the smaller variety, that is, on a level with the sinus and usually directed outward at a wide angle from the midline.

Additional variation may be seen in the ovicells. Usually they are similar to those described by Ryland (1965) and Powell (1970). They can, however, develop radial fluted patterns that are somewhat similar to that found in *S. unicornis*. When present, the fluting in *S. errata* is primarily confined to the distal periphery of the ovicell. A few specimens have been found where radial pattern tends to extend across the entire ovicell.

In either case, the fluting apparently is not as well-developed as in *S. unicornis.*

Genus **STEPHANOSELLA** Canu and Bassler, 1917

Stephanosella cornuta (Gabb and Horn, 1862)
Plate 2, figure 2

Hepteschurellina cornuta Gabb and Horn, 1862, pl. 20, fig. 31, p. 147.
Schizoporella cornuta (Gabb and Horn). Osburn, 1952, p. 320, pl. 37, figs. 9–11.
Schizoporella cornuta (Gabb and Horn). Cheetham and Sandberg, 1964, p. 1030, text-figs. 31, 34.
Stephanosella cornuta (Gabb and Horn). Powell, 1967, p. 278.

Description.—Zoarium encrusting; zooecium somewhat elliptical to polygonal; frontal tremocyst thick, coarsely perforate; aperture distally circular with broad V-shaped sinus; avicularia usually paired, lateral, ovoid to subtriangular in outline, on umbonate processes proximal to aperture; ovicell globular, imperforate, radially-grooved with outer ends forming deep pits.

Diagnosis.—Usually paired, ovoid to subtrigonal avicularia on umbonate processes that are situated lateral and proximal to orifice. Ovicell is globular, imperforate and radially-grooved with the outer ends forming deep pits.

Measurements (in mm).—

	length of zooid	*width of zooid*	*length of primary orifice including sinus*	*width of primary orifice*	*length of avicularia*	*width of avicularia*	*length of ovicell*	*width of ovicell*
USNM 218161								
Number of Measurements	20	20	20	20	20	20	20	20
Mean	0.420	0.252	0.094	0.110	0.100	0.075	0.165	0.205
Standard Deviation	0.073	0.039	0.016	0.015	0.017	0.016	0.015	0.019
Range	0.32–0.62	0.17–0.33	0.07–0.12	0.09–0.15	0.08–0.13	0.05–0.11	0.13–0.19	0.17–0.25

Distribution.—Miocene: Jamaica, North Carolina; Pleistocene: California, Louisiana, Florida, Virginia; Recent: Alaska to Galapagos Islands, Massachusetts to Gulf of Mexico, Caribbean, West Africa.

Occurrence in this study.—Localities 17d, 18d, 20b, 22b, 25a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218161.

Discussion.—Powell (1967, pp. 277–278) maintains that because of large variation in frontal porosity in related species of various genera, such frontal perforation should not be regarded as a generic character particularly when there is agreement with other important structures. Consequently, he has placed *Schizoporella cornuta* (Gabb and Horn, 1862) as well as *Schizoporella dissimilis* (Osburn, 1952) in the genus *Stephanosella,* because of similarity in the characteristics of the orifice, avicularia and ovicell.

Family **CLEIDOCHASMATIDAE**
Cheetham and Sandberg, 1964

Genus **HIPPOPORIDRA** Canu and Bassler, 1927

Hippoporidra calcarea (Smitt, 1873)
Plate 3, figure 2

Lepralia edax forma *calcarea* Smitt, 1873, p. 63, pl. 11, figs. 220, 223.
Hippoporidra janthina (Smitt). Cheetham and Sandberg, 1964, p. 1033, text-fig. 36.
Hippoporidra calcarea (Smitt). Scolaro, 1970, p. 97.

Description.—Zoarium encrusting gastropod shells, often with irregular branches; zooecia irregularly polygonal. Frontal pleurocyst thick, with marginal pores and one to two rows of areolae often separated by prominent ridges uniting below orifice to form an umbo; orifice subcircular, separated by strong condyles situated close to broadly-rounded, proximal lip; frontal avicularia small, with crossbar, ovate-acuminate, usually proximolateral, rostra frequently elevated; interzooecial avicularia large, ovate-acuminate to subtrigonal, with trilobate crossbar, strongly elevated rostra; ovicells prominent, usually with tubercle situated near the center of a smooth semicircular to elliptical arc, which is surrounded by a thin fold or line.

Diagnosis.—Associated with parugids and mollusks. Frontal is thick with marginal pores and prominent ridges forming umbo below orifice. Frontal avicularia are small with a crossbar and an elevated rostrum while interzooecial avicularia are large with a trilobate crossbar and an elevated rostrum. Ovicell is smooth with central tubercle and a marginal thin fold.

Distribution.—Because of the confusion of this species with what has been called *Hippoporidra janthina* (Smitt, 1873), distribution is in doubt. Definite occurrences are reported from: Miocene: Maryland, Florida; Pleistocene: Virginia; Recent: From Cape Hatteras south (found north of Cape Hatteras in Tropical Province [Maturo, 1968]).

Occurrence in this study.—Localities 17c, 17d, 18b, 18d, 20b, 22b.

Type information.—Holotype: unknown. Figured hypotype: USNM 218164.

Measurements (in mm).—

	length of zooid	*width of zooid*	*length of primary orifice including sinus*	*width of primary orifice*	*length of frontal avicularia*	*width of frontal avicularia*	*length of inter-zooecial avicularia*	*width of inter-zooecial avicularia*	*length of ovicell*	*width of ovicell*
USNM 218164										
Number of Measurements	20	20	20	20	20	20	20	20	20	20
Mean	0.271	0.205	0.093	0.076	0.093	0.052	0.182	0.134	0.106	0.143
Standard Deviation	0.086	0.060	0.010	0.007	0.015	0.009	0.023	0.023	0.011	0.016
Range	0.15–0.49	0.15–0.37	0.07–0.12	0.07–0.09	0.07–0.12	0.04–0.07	0.13–0.22	0.08–0.17	0.08–0.12	0.10–0.17

Discussion.—There is considerable confusion over the proper placement of specimens in the closely-related *H. edax–calcarea–janthina* complex. Cook (1964, pp. 26–28) in a discussion on *H. edax* (Busk, 1861) and *H. janthina* states that the latter species has a wider, shallower sinus and greater frequency of frontal pores, and tentatively placed all western Atlantic records under the name *H. janthina.* Maturo (1968, p. 278) and Scolaro (1970, p. 97) use the name *H. calcarea* (Smitt, 1873) for the tropical western Atlantic species of *Hippoporidra.* The confusion, partly clarified by Cook (1964), was further clarified in recent (1976) correspondence with her. With Cook's kind permission (June 24, 1976), pertinent portions of this correspondence are herein quoted:

The vitally important thing about *Hippoporidra* is its highly integrated colony growth—and the correlations of characters this produces makes all the distinction between it and other, somewhat similar, genera.

Hippoporidra has a rigidly controlled budding pattern. Although the zooids of the secondary zones look 'irregularly budded' they are *not.* The primary zone is very regular and the zooids are monomorphic. Then frontal budding starts and things get complicated.

In a 'simple' mamillate colony small regularly spaced groups of frontally budded zooids appear first. These then bud male zooids frontally, and the intervening areas bud more autozooids and sometimes females with ovicells (brooding zooids). Later—(probably after brooding) the whole process is reversed—the raised male groups bud autozooids, and females and the autozooid groups bud raised male groups. Sometimes there is a pigment difference between groups—and in any one colony *either* the males *or* the autozooids are pigmented—it is consistent within the colony but *not* within population!

In 'branched' species—the whole thing is even more complex. It appears to be related to breeding and to colony water currents . . . .

Male zooids are distinctive . . . . They have a lot of 'carried-up' marginal pores, very small, tuberculate orifices, and the zooids are large and raised above the colony surface. Males have a reduced number of tentacles, which are unciliated, and no gut.

1) *calcarea* is a *Hippoporidra*—Smitt's specimens were ontogenetically old, and several were fragments of erect 'branched' colonies—which occurs in the west African *senegambiensis* and in *picardi,* but not in European *edax.*

2) *janthina* is *not* a *Hippoporidra.* It is simply encrusting, with little frontal budding and none of the colony organization of *Hippoporidra.* There is no pagurid or mollusc association and the zooids are monomorphic. The zooids are much larger than those of the primary zone of *H. calcarea,* the frontal wall has numerous pseudopores as well as marginal septulae. The orifices have a wider, shallow sinus and there are no interzooidal avicularia with 'ligulate' bar structure.

3) Canu and Bassler (1927) erected the genus *Hippotrema* for *janthina* Smitt—it is certainly a valid genus and so the name is *not* available for any form of Hippoporidra . . . . Note also that contrary to Smitt's statement (1873:64), specimens of *H. edax* do have both avicularia and ovicells, and patterned budding of male zooids.

Family MICROPORELLIDAE Hincks, 1880

Genus MICROPORELLA Hincks, 1877

Microporella ciliata (Pallas, 1766)

Plate 3, figure 3

Eschara ciliata Pallas, 1766, p. 38.
Microporella ciliata (Pallas). Hincks, 1880, p. 206, pl. 28, figs. 1–5.
Microporella ciliata (Pallas). Maturo, 1957, p. 54, figs. 60, 61.

Description.—Zoarium encrusting; zooecia ovate to hexagonal, often separated by narrow groove; frontal tremocystal, inflated, granular, having numerous small tremopores; lunate to ovate, slightly elevated ascopore with proximal portion frequently raised into small umbonate process; orifice semicircular, slightly raised, proximal border straight, peristome bordered laterally and distally by four to seven oral spines; avicularium frontal, usually single, small, ovate with short pointed elevated rostra, situated lateral and proximal to ascopore, directed laterally; ovicell globose, smooth to granular, perforate, occasionally with umbonate process, and with collar around aperture.

Diagnosis.—Zooecia, separated by narrow grooves, have an inflated, granular, perforate frontal that has an elevated ascopore. Peristome is bordered laterally and distally by four to seven oral spines. Ovicell is perforate and possesses a collar around the aperture.

Distribution.—Miocene: Florida, Maryland; Pliocene: North Carolina; Pleistocene: California, Virginia; Recent: Cosmopolitan, boreal to tropical waters at depths from shore to 360 fathoms.

Occurrence in this study.—Localities 17c, 17d, 17e, 17f, 20b, 22a, 22b.

Type information.—Holotype: unknown. Figured hypotype: USNM 218165.

Measurements (in mm).—

	length of zooid	*width of zooid*	*length of primary orifice including sinus*	*width of primary orifice*	*length of avicularia*	*width of avicularia*	*length of ovicell*	*width of ovicell*
USNM 218165								
Number of Measurements	20	20	20	20	20	20	10	10
Mean	0.522	0.308	0.077	0.118	0.065	0.044	0.175	0.268
Standard Deviation	0.100	0.051	0.011	0.028	0.015	0.010	0.013	0.022
Range	0.35–0.70	0.22–0.42	0.05–0.10	0.08–0.18	0.04–0.10	0.03–0.06	0.15–0.20	0.23–0.30

Discussion.—*Microporella ciliata* exhibits much variation as shown by descriptions by Maturo (1957, p. 54), Osburn (1944, p. 45; 1947, p. 377; 1952, p. 375), and Weisbord (1967, p. 72). Cook (1968b, p. 207) notes that because of this great amount of variation, it was necessary to restrict her West African specimens to the form illustrated by Hincks (1880, pl. 28, fig. 1) and, that based upon collections from the British Museum, there appear to be two major forms. The first form has the avicularium located at or near the level of the ascopore, has long setiform mandibles, has a flattened frontal, and has non-perforate ovicells. In the second form, the avicularium is directed laterally and is situated closer to the ascopore. Except for the shape of the avicularian mandibles and infrequency of perforate ovicells, Cook (1968b, p. 207) states that this second form resembles *M. orientalis* Harmer, 1957. The specimens found occurring in the Virginia Pleistocene appear to possess characters attributable to Cook's second form. However, there is a great paucity of avicularia in all colonies examined.

Family **SMITTINIDAE** Levinsen, 1909

Genus **PARASMITTINA** Osburn, 1952

Parasmittina nitida (Verrill, 1875a)
Plate 3, figure 4

Discopora nitida Verrill, 1875a, p. 415, pl. 7, fig. 3.
Parasmittina nitida (Verrill) Morphotype A. Maturo and Schopf, 1968, p. 41, figs. 13A–B.
Parasmittina nitida (Verrill). Humphries, 1975, p. 29, pl. 3, figs. 1–12.

Description.—Zoarium encrusting, unilamellar or multilamellar; zooecia elongate, quadrate to hexagonal, separated from adjacent zooids by distinct raised wall; frontal convex in young and flattened in adults, with marginal row of large areolar pores becoming funnel-shaped and separated by prominent ridges in mature forms, young with some additional frontal pores; tubercles low, numerous, covering much of the frontal surface, often coalescing into low rounded knobs in older zooids; orifice somewhat square to round, condyles reduced, lyrule low, rectangular, straight free margin, about one-third to one-quarter width of orifice; orificial collar low, proximal border without projections, gently sloping down to lyrule; ovicell large, globular, surface smooth, perforated by many small round pores, surrounded laterally and distally by imperforate rim which becomes rough and tuberculate in older forms; avicularium frontal, single, small, acute, situated proximal or proximolateral to orifice, rostra directed proximally and frequently elevated.

Diagnosis.—Zooecia separated from each other by a raised wall. Frontal, with many low tubercles and knobs, has a marginal row of large pores, separated by prominent ridges. Ovicell large and smooth with many small, round pores, and with an imperforate rim that can be rough to tuberculate.

Measurements (in mm).—

	length of zooid	*width of zooid*	*length of primary orifice including sinus*	*width of primary orifice*	*length of avicularia*	*width of avicularia*	*length of ovicell*	*width of ovicell*
USNM 218166								
Number of Measurements	20	20	20	20	20	20	10	10
Mean	0.396	0.186	0.095	0.109	0.123	0.089	0.224	0.275
Standard Deviation	0.057	0.020	0.010	0.014	0.023	0.016	0.056	0.016
Range	0.30–0.48	0.15–0.23	0.08–0.11	0.09–0.14	0.10–0.20	0.08–0.13	0.19–0.23	0.25–0.30

Distribution.—Because of confusion regarding the morphotypes of this species, as well as their relationship to other closely-related species such as *P. trispinosa* (Johnston, 1838), *P. spathulata* (Smitt, 1873), and *P. jeffreysi* (Norman, 1876), geologic and geographic distributions are in doubt. Present distribution appears to be from New England to Brazil. Humphries (1975, p. 20) reports a documented distribution of *P. nitida* morphotype A as being from Long Island Sound to Vero Beach, Florida.

Occurrence in this study.—Locality 20b.

Type information.—Lectotype: USNM 4340, morphotype A, colony 38*. Paralectotypes: YPM 2898 (4791), morphotype A; USNM 4340, colony 38; USNM 4333; YPM 2849, morphotype B. Figured hypotype: USNM 218166.

Discussion.—Maturo and Schopf (1968, pp. 41–48) discuss in detail the problems concerning this species, particularly with regard to two morphotypes, which they label A and B. The Virginia material is very similar to their *P. nitida*—morphotype A, with only minor differences in the shape of the orifice and prominence of the condyles. Humphries (1975) in a detailed study of the two morphotypes designated by Maturo and Schopf (1968) has shown that they are separate species. *P. nitida* morphotype A is designated as *P. nitida* (Humphries, 1975 [p. 29]).

Family **CHEILOPORINIDAE** Bassler, 1936

Genus **CRYPTOSULA** Canu and Bassler, 1925

Cryptosula pallasiana (Moll, 1803)
Plate 3, figure 5

Eschara pallasiana Moll, 1803, p. 57, pl. 3, figs. 13A, B.
Cryptosula pallasiana (Moll). Canu and Bassler, 1925, p. 33, pl. 7, fig. 11.
Cryptosula pallasiana (Moll). Weisbord, 1967, pp. 62–68, pl. 2, fig. 14; pl. 6, figs. 3, 4.

Description.—Zoarium encrusting; zooecia hexagonal to subquadrangular, moderately large; orifice large, suboval to bell-shaped, sides nearly parallel; posterior broadly arcuate, wide, shallow; anterior narrower, more strongly arched; cardelles small; peristome raised, forming conspicuous border; frontal tremocyst with large polygonal pores; no ovicells; avicularia absent.

Diagnosis.—Large suboval to bell-shaped orifice with a raised peristome forming a conspicuous border. Frontal with large polygonal pores.

Distribution.—Pliocene: Venezuela; Pleistocene: Virginia; Recent: From Cape Hatteras north, found south of Cape Hatteras to Beaufort, NC, in shallow waters adjacent to shore (Maturo, 1968), Alaska to Baja California, Mexico, littoral zone to less than 28 fathoms.

Measurements (in mm).—

	length of zooid	*width of zooid*	*length of ovicell*	*width of ovicell*
USNM 218167				
Number of Measurements	20	20	20	20
Mean	0.591	0.357	0.205	0.167
Standard Deviation	0.053	0.056	0.009	0.013
Range	0.53–0.75	0.23–0.44	0.19–0.23	0.15–0.20

Occurrence in this study.—Localities 17b, 17c, 17d, 18b, 20a, 20b, 22a, 22b, 25a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218167.

Phylum **MOLLUSCA**

Class **BIVALVIA** Linné, 1758

Family **NUCULIDAE** Gray, 1824

Genus **NUCULA** Lamarck, 1799

Nucula major Richards, 1944
Plate 4, figures 3, 4

Nucula major Richards, 1944, p. 8, figs. 5, 6.
Nucula major Richards. Richards, 1962, p. 51, pl. 1, figs. 10, 11.

Diagnosis.—Shell gigantic for the genus, smooth, heavy, solid. Surface with low, concentric undulations. Interior ventral margin smooth. Beaks forward, low. Hinge taxodont. Ligamental pit broken.

Measurements.—Length, 47.5 mm; height, 38.0 mm.

Distribution.—Pleistocene: New Jersey and Virginia; Recent: Extinct.

Occurrence in this study.—Locality 23.

Type information.—Holotype: $ANSP_p$ 15938. Figured hypotype: ANSP 64321.

Discussion.—This species is extremely rare, being reported from five more or less broken specimens. The largest of the Virginia specimens is sufficiently entire for diagnostic description. Richards (1962, p. 51) suggests affinities with *N. shaleri* Dall, 1898 (p. 505) from the Pliocene of Martha's Vineyard. That species differs from *N. major* by its smaller size, more trigonal outline, more fragile shell, stronger concentric sculpture, and denticulate interior ventral margin (cf. Pl. 4, fig. 5).

Nucula proxima Say, 1820
Plate 4, figures 5, 6

Nucula proxima Say, 1820, p. 40.
Nucula proxima Say. Dall, 1898, p. 574.
Nucula proxima Say. Gardner, 1943, p. 19, pl. 1, figs. 1, 2, 4, 5.
Nucula proxima Say. Richards, 1962, p. 51, pl. 1, fig. 1.
Nucula proxima Say. Hampson, 1971, pp. 333–342.

Diagnosis.—Shell small, solid. Surface with low, irregular, concentric ridges, obsolete in early growth, increasingly strong with mature growth. Interior ventral margin crenulate. Beaks forward, high. Hinge taxodont. Ligamental pit narrowly triangular, oblique.

Measurements.—Length, 7.0 mm; height, 6.0 mm.

Distribution.—Miocene: New Jersey to Virginia; Lower Pliocene: Virginia to Florida; Upper Pliocene: North Carolina to Florida; Pleistocene: New York to Florida; Recent: Nova Scotia to Florida and Texas (Northern race: Nova Scotia to Long Island; Southern race: New Jersey to Florida and Texas).

Occurrence in this study.—Localities 15, 17b, 17c, 17d, 17e, 17f, 18a, 18b, 18d, 18e, 19a, 20b, 21a, 22b, 26a.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218170.

Discussion.—*N. proxima* is well established in the Miocene. In the Virginia Yorktown Pliocene, it can be confused with the more oval *N. diaphana* Lea, 1843. *N. taphria* Dall, 1898, is a heavier Mio-Pliocene species with periodic incised growth lines. The young of *N. shaleri* Dall, 1894 (Pl. 4, fig. 5), have been confused with *N. proxima*, but *N. shaleri* is much more elongate. It is reported from the Pliocene (?) of Gay Head, Martha's Vineyard, Massachusetts. The recently described species, *N. annulata* Hampson, 1971, ranges from Cape Cod to Virginia and is closely related to *N. proxima*. *N. annulata* differs in its broader and shorter ligament, more bluntly terminated chondrophore, more prominent umbos, stronger sculpture, smaller size, and different life habits. A critical re-examination of our material has not yielded *N. annulata* but more extensive collecting of clay beds might produce it. *N. annulata* is easily confused with juvenile *N. proxima*, and has likely been overlooked in Pleistocene collections.

Family **NUCULANIDAE** Adams and Adams, 1858

Genus **NUCULANA** Link, 1807

Nuculana acuta (Conrad, 1832)
Plate 4, figures 7, 8

Nucula acuta Conrad, 1832, p. 32, pl. 5, fig. 1; pl. 6, fig. 3.
Leda acuta (Conrad). Dall, 1898, pp. 592–593.
Nuculana acuta (Say). [*sic*] Gardner, 1943, pp. 9, 12.
Nuculana acuta Conrad. [*sic*] Abbott, 1954, p. 338.
Nuculana acuta (Conrad). Richards, 1962, p. 52, pl. 1, figs. 12, 13.

Diagnosis.—Shell small, solid, pointed posteriorly. Surface with low, even, concentric threads. Hinge taxodont. Beaks central.

Measurements.—Length, 6.2 mm; height, 3.5 mm.

Distribution.—Lower Pliocene: Virginia to Florida and Texas; Upper Pliocene: North Carolina to Florida; Pleistocene: Maryland to Florida and Texas, Panama; Recent: Massachusetts to Florida and the West Indies and Brazil.

Occurrence in this study.—Localities 16, 17b, 17c, 17e, 17f, 18b, 18c, 19a, 21a, 26a, 28, 29.

Type information.—Syntype: $ANSP_p$ 30613. Figured hypotype: USNM 218171.

Discussion.—This species is scarce throughout the Virginia Pleistocene.

Family **SOLEMYACIDAE** Adams and Adams, 1857

Genus **SOLEMYA** Lamarck, 1818

Solemya velum Say, 1822
Plate 4, figures 1, 2

Solemya velum Say, 1822, p. 317.
Solemya velum Say. Abbott, 1954, p. 333, pl. 27, fig. a.

Diagnosis.—Shell of small to moderate size, elongate, thin, very fragile. Surface smooth. Color pattern preserved, of faint radial brownish bands with much wider interspaces. Hinge lacking.

Measurements.—Length, 16.0 mm; height, 6.5 mm.

Distribution.—Pleistocene: Virginia; Recent: Nova Scotia to Florida.

Occurrence in this study.—Locality 17c.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218168.

Discussion.—Two specimens of this very fragile clam were found by Drez (unpublished data) inside a large specimen of *Busycon* Röding, 1798, from locality 17c. This species is previously unreported in the Pleistocene.

Family **ARCIDAE** Lamarck, 1809

Genus **ANADARA** Gray, 1847

Anadara ovalis (Bruguière, 1789)
Plate 4, figures 9, 10

Arca ovalis Bruguière, 1789, p. 110.
Arca campechiensis Gmelin, 1790, p. 3312.
Arca pexata Say, 1822, p. 268.
Arca americana Reeve, 1844, fig. 21.
Scapharca (*Argina*) *campechiensis* (Gmelin). Dall, 1898, pp. 650–652.
Anadara ovalis Bruguière. [*sic*] Abbott, 1954, p. 345, pl. 27, fig. t.
Anadara ovalis (Bruguière). Richards, 1962, p. 53, pl. 2, figs. 3–4.

Diagnosis.—Shell fairly large, broadly oval, heavy, solid. Surface with radial ribs and deep, narrow interspaces; ribs with a low, central groove. Inner ventral margin denticulate. Beaks low, pointing forward.

Measurements.—Length, 34.5 mm; height, 30.0 mm.

Distribution.—Upper Pliocene: North Carolina; Pleistocene: Massachusetts to South Carolina, Louisiana, Panama; Recent: Massachusetts to Texas and the West Indies and Brazil.

Occurrence in this study.—Localities 7, 12, 15, 17e, 17f, 18e, 20b.

Type information.—Holotype: unknown. Figured hypotype: USNM 218172.

Discussion.—Dall (1898, p. 651) discusses the well-defined Recent geographic variation of this far-ranging species. Our collections are meager and no attempt has been made to correlate the fossils with a particular race. Should sufficient material become available, the species might well prove a good climatic index.

Anadara transversa (Say, 1822)
Plate 4, figures 11, 12

Arca transversa Say, 1822, p. 296.
Scapharca (*Scapharca*) *transversa* (Say). Dall, 1898, p. 645.
Anadara transversa Say. [*sic*] Abbott, 1954, p. 345, pl. 27, fig. s.
Anadara transversa (Say). Richards, 1962, p. 53, pl. 2, figs. 12–13.

Diagnosis.—Shell of moderate size, solid, fairly heavy; rectangular and compressed in young specimens, more inflated and ovate-rectangular in mature shells.

Measurements.—Length, 33.5 mm; height, 23.5 mm.

Distribution.—Lower Pliocene: Texas; Upper Pliocene: Florida; Pleistocene: Massachusetts to Florida and Texas; Recent: Massachusetts to Texas and the Caribbean.

Occurrence in this study.—Localities 17b, 17c, 17d, 18a, 18b, 18d, 19a, 20a, 20b, 21a, 22a, 22b, 26a, 27, 28, 29.

Type information.—Holotype: $ANSP_p$ (missing). Figured hypotype: USNM 218173.

Discussion.—In mixed Plio-Pleistocene material, *A. transversa* is easily confused with the more elongate *A. improcera* (Conrad, 1845) and slightly more oval *A. plicatura* (Conrad, 1845). A good discussion of the latter forms and their relationships can be found in Olsson and Harbison (1953, pp. 38–39).

Genus **NOETIA** Gray, 1857

Noetia (Eontia) ponderosa (Say, 1822)
Plate 4, figures 15–17, 21

Arca ponderosa Say, 1822, p. 267.
Arca contraria Reeve, 1844, pl. 8, fig. 55.
Arca elegans Philippi, 1847, p. 92.
Arca (*Noetia*) *ponderosa* Say. Dall, 1898, p. 633.
Eontia ponderosa (Say). MacNeil, 1938, p. 24, pl. 3, figs. 9–12.
Noetia ponderosa Say. [*sic*] Abbott, 1954, p. 346, pl. 27, fig. z.
Noetia ponderosa (Say). Bousfield, 1961, pp. 1–3.
Noetia (*Eontia*) *ponderosa* (Say). Richards, 1962, p. 54, pl. 2, figs. 1–2.

Diagnosis.—Shell large, massive, bluntly tapering posteriorly. Proportions variable. Sculpture of radial ribs coarsening posteriorly; ribs commonly with a low central groove or grooves. Ventral interior margin denticulate. Beaks high. Ligamental region perpendicularly striate.

Measurements.—Length, 60.5 mm; height 45.0 mm; figures 15, 16: Length, 39.5 mm; height, 34.0 mm; figures 17, 21.

Distribution.—Upper Pliocene: Florida (?); Pleistocene: Bay of Fundy (doubtful) and Massachusetts, New Jersey to Florida and Louisiana; Recent: Virginia to Florida and Texas.

Occurrence in this study.—Localities 7, 10, 11, 15, 17b, 17c, 17d, 18a, 22a, 22b, 26a, 29.

Type information.—Holotype: unknown. Figured hypotypes: USNM 218174, 218175.

Discussion.—Although all Virginia Pleistocene species of *Noetia* have been assigned by previous workers to *N. ponderosa,* it seems likely that many of the Virginia Pleistocene records of this species will, upon detailed examination, prove to be better assigned to *N. palmerae* (MacNeil, 1938). Most of the specimens in our collection appear to be more elongate than is typical of *N. ponderosa.* However, until a comprehensive analysis of these two species is performed, the authors consider it prudent to include the commonly-occurring elongate forms as a variation of *N. ponderosa.*

Family **MYTILIDAE** Rafinesque, 1815

Genus **MYTILUS** Linné, 1758

Mytilus edulis Linné, 1758
Plate 4, figures 18, 19

Mytilus edulis Linné, 1758, p. 705.
Mytilus edulis Linné. Dall, 1898, p. 788.
Mytilus edulis Linné. Abbott, 1954, p. 354, pl. 35, fig. m.
Mytilus edulis Linné. Richards, 1962, p. 56, pl. 4, figs. 11–12.
Mytilus edulis Linné. Durham and MacNeil, 1967, p. 331.

Diagnosis.—Shell of moderate size, thin, fragile. Surface smooth; beaks terminal. Color a deep blue in living material, oxidizing to a pale lilac in the fossils.

Measurements.—Length, 11.0 mm; height, 19 mm.

Distribution.—Miocene: Pacific Northwest (Oregon and Washington); Pliocene: Pacific Northwest, Great Britain, the Netherlands, Belgium; Pleistocene: Pacific Northwest, Labrador to Virginia, South Carolina?, Northern Europe; Recent: Arctic Ocean to South Carolina, California, and Northern Europe.

Occurrence in this study.—Localities 17c, 22a.

Type information.—Holotype: LS, uncatalogued. Figured hypotype: USNM 218176.

Discussion.—The species is rare in the Virginia Pleistocene. *M.* (*Perna*) *conradianus* d'Orbigny, 1852, of the underlying Yorktown Pliocene is a relatively more narrow, less inflated form.

Genus ISCHADIUM Jukes-Browne, 1905

Ischadium recurvum (Rafinesque, 1820)

Mytilus recurvus Rafinesque, 1820, p. 320.
Mytilus hamatus Say, 1822, p. 265.
Brachidontes (*Ischadium*) *recurvus* (Rafinesque). Gardner, 1943, p. 29, pl. 1, figs. 7–8.
Brachidontes recurvus Rafinesque. [*sic*] Abbott, 1954, p. 353, pl. 35, fig. n.
Brachidontes recurvus (Rafinesque). Richards, 1962, p. 56, pl. 4, fig. 17.
Ischadium recurvum (Rafinesque). Abbott, 1974, p. 430, fig. 5048.

Diagnosis.—Shell of moderate size, thin, fragile. Surface radially ribbed; beaks terminal. Interior nacreous, opalescent.

Distribution.—Lower Pliocene: Virginia (?); Upper Pliocene: North Carolina to Florida; Pleistocene: Massachusetts to North Carolina, Louisiana; Recent: Cape Cod to the West Indies.

Occurrence in this study.—Localities 9, 17d, 18b, 18d, 21a, 26a, 27.

Type information.—Holotype: unknown.

Discussion.—A complete fossil specimen was not found, but Virginia Pleistocene fragments are characteristic.

Genus CRENELLA Brown, 1827

Crenella glandula Totten, 1834

Crenella glandula Totten, 1834, p. 367.
Crenella glandula Totten. Abbott, 1954, p. 350, pl. 28, fig. j.
Crenella glandula Totten. Richards, 1962, p. 57, pl. 5, figs. 3–4.
Crenella glandula Totten. Richards, 1966, p. 20, pl. 1, figs. 15–16.

Diagnosis.—Shell small, rather large for the genus, oval, inflated. Sculpture of even, divaricating ribs.

Distribution.—Pleistocene: Quebec (?), Massachusetts to Virginia; Recent: Labrador to North Carolina.

Occurrence in this study.—Locality of Oaks, 1964, table C-1 (specific locality not given).

Type information.—Holotype: unknown.

Discussion.—This species was identified from a core sample (location not given) which Oaks (1964, table C-1) refers to as "Yorktown", but which Richards (1966) reported as Pleistocene. Assuming his identifications to be correct, this pre-Great Bridge horizon contains an admixture of Pliocene and Pleistocene species with the Pleistocene influence predominating, very similar to the mixed fauna of the Wicomico Formation (Yarmouth) of South Carolina (Colquhoun, Herrick, and Richards, 1968, pp. 214–218). *C. precursor* Gardner, 1943, of the underlying Yorktown and Croatan Pliocene has fewer spiral threads, but could easily be confused with *C. glandula.*

Genus MODIOLUS Lamarck, 1799

Modiolus squamosus Beauperthuy, 1967
Plate 4, figures 13, 14

Modiolus modiolus squamosus Beauperthuy, 1967, p. 39.
Modiolus americanus (Leach). Richards and Campbell, 1972, p. 12.
Modiolus modiolus squamosus Beauperthuy. Abbott, 1974, p. 435, fig. 5088.

Diagnosis.—Shell large, thin, inflated. Surface smooth save for growth lines. Beaks round, swollen, a little back from the anterior end of the shell. Color in life an even, dark brown: fossils a faded brown, color stronger on moistened specimens.

Measurements.—Length, 44.5 mm; height, 88.0 mm.

Distribution.—Pleistocene: Virginia and Florida; Recent: North Carolina to Venezuela.

Occurrence in this study.—Localities 17b, 17c, 17d, 22a, 22b, 22c, 26a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218177.

Discussion.—This species is locally common. At locality 17, articulated valves apparently in life position were found associated with plant remains suggesting *Spartina.* Our specimens show considerable variation in the width of individual specimens but the other characters seem constant. It is suspected that some of the more southern Pleistocene records of *M. modiolus* (Linné, 1758) are or include this species. *M. gigas* Dall, 1897, of the Yorktown Pliocene is larger, less inflated, and has a rounded rather than angled dorsal margin.

Genus GEUKENSIA Poel, 1959

Geukensia demissa (Dillwyn, 1817)

Mytilus demissus Dillwyn, 1817, p. 314.
Modiola plicatula Lamarck, 1819, p. 113.
Modiola semicostata Conrad, 1837, p. 244, pl. 20, fig. 7.
Modiolus (*Brachydontes*) *demissus* (Dillwyn). Dall, 1898, pp. 794–795.
Volsella demissa Dillwyn. [*sic*] Abbott, 1954, pl. 28, fig. h.
Modiolus demissus (Dillwyn). Richards, 1962, p. 56, pl. 4, fig. 19.
Archatula demissa (Dillwyn). Pojeta, 1971, pp. 17, 32, pl. 11, fig. 32.
Geukensia demissa (Dillwyn). Abbott, 1974, p. 437, fig. 5105.

Diagnosis.—Shell large, thin, narrow, nacreous within. Sculptured with strong radial cords.

Distribution.—Lower Pliocene: Florida; Pleistocene: New Jersey to South Carolina, Louisiana; Recent: Nova Scotia to Florida, San Francisco Bay (introduced).

Occurrence in this study.—Localities 9, 17d, 22c.

Type information.—Holotype: unknown.

Discussion.—This salt marsh species is very rare in the Virginia Pleistocene, and complete specimens are very difficult to extract from the sediment.

Genus **MUSCULUS** Röding, 1798

Musculus lateralis (Say, 1822)
Plate 4, figure 20

Mytilus lateralis Say, 1822, p. 264.
Modiolaria lateralis (Say). Dall, 1898, p. 807.
Musculus lateralis Say. [*sic*] Abbott, 1954, p. 355, fig. 75d.
Musculus lateralis (Say). Richards, 1962, p. 57, pl. 5, figs. 7–8.

Diagnosis.—Shell small to very small, thin, inflated, fragile. Sculpture of radial threads on the anterior and posterior; center of shell smooth. Outline of shell quadrate to broadly oval. Beaks low, small, positioned a little back from the anterior end.

Distribution.—Pliocene: Florida; Pleistocene: Virginia to Florida; Recent: North Carolina to Venezuela, Brazil.

Occurrence in this study.—Locality 17b.

Type information.—Holotype: ANSP 55518. Figured hypotype: USNM 218178.

Discussion.—This species is represented in our collections by a single diagnostic fragment. *M. lateralis* differs from the Pliocene species *M. virginica* (Conrad, 1867) by its larger size, greater inflation, and in lacking the posterior reticulation characteristic of the latter species.

Family **PECTINIDAE** Rafinesque, 1815

Genus **ARGOPECTEN** Monterosato, 1889

Argopecten gibbus (Linné, 1758)
Plate 5, figures 2, 5

Ostrea gibba Linné, 1758, p. 698.
Aequipecten (*Plagioctenium*) *gibbus* Linné. [*sic*] Abbott, 1954, p. 368, pl. 33, fig. j.
Aequipecten irradians (Lamarck). Richards, 1962, p. 55.
Pecten (*Plagioctenium*) *gibbus* (Linné). Gardner, 1943, p. 31, pl. 5, fig. 3.
Argopecten gibbus (Linné). Waller, 1969, pp. 36–38, pl. 8, figs. 1–4.

Diagnosis.—Shell of moderate size, circular, thin but strong. Sculpture of about 20 radial ribs crossed by growth lines and fine concentric threads. Ears relatively large, the anterior somewhat larger than the posterior.

Measurements.—Length, 52.0 mm; height, 45.0 mm.

Distribution.—Upper Pliocene: North Carolina? to Florida?; Pleistocene: Virginia to Florida, Panama; Recent: Maryland to the Antilles.

Occurrence in this study.—Localities 17b, 17c, 18a, 18b, 26a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218180.

Discussion.—"*Argopecten gibbus* differs from *A. irradians* in having a very slightly right-convex to left-convex, rather than distinctly right-convex, shell; dorsal margins of right valve that form a shallow **V** dorsal to the outer ligament; a shallower byssal notch commonly without ctenolium in mature individuals; and disk flanks that generally have less distinct costae" (Waller, 1969). Waller does not address himself to Gardner's Waccamaw and Caloosahatchee records, but seems to indicate that the Caloosahatchee records known to him are better referred to Unit A Pleistocene. With the exception of the Mt. Trashmore section (loc. 18), *A. gibbus* is very rare in Virginia Pleistocene deposits. The underlying Yorktown contains two species of *Argopecten*, *A. eboreus* (Conrad, 1833) and *A. comparilis* (Tuomey and Holmes, 1855), both of which are well discussed by Gardner (1943, pp. 36–37) and Waller (1969, pp. 53–61).

Family **ANOMIIDAE** Rafinesque, 1815

Genus **ANOMIA** Linné, 1758

Anomia simplex d'Orbigny, 1845
Plate 5, figures 3, 6

Anomia simplex d'Orbigny, 1845, p. 367, pl. 38, figs. 31–33.
Anomia simplex d'Orbigny. Dall, 1898, p. 784.
Anomia simplex d'Orbigny. Abbott, 1954, p. 372, pl. 35, fig. k.
Anomia simplex d'Orbigny. Richards, 1962, p. 56, pl. 4, fig. 18; pl. 5, fig. 22.

Diagnosis.—Shell of moderate size, irregularly oval to circular, compressed to well inflated, thin but strong. Surface rough, irregular. Interior with a central, rectangular callus containing three round muscle scars.

Measurements.—Length, 28.0 mm; height, 27.0 mm.

Distribution.—?Miocene: Dominican Republic?; Lower Pliocene: Virginia to Florida; Upper Pliocene: North Carolina to Florida; Pleistocene: Massachusetts to Florida and Gulf States; Recent: Nova Scotia to West Indies, Brazil.

Occurrence in this study.—Localities 17b, 17c, 17d, 18a, 18b, 18d, 20a, 22a, 22b.

Type information.—Syntype: BMNH 1854.10.4.632. Figured hypotype: USNM 218181.

Family **OSTREIDAE** Rafinesque, 1815

Genus **CRASSOSTREA** Sacco, 1897

Crassostrea virginica (Gmelin, 1791)
Plate 5, figures 1, 8

Ostrea virginica Gmelin, 1791, p. 3336.
Ostrea virginica Gmelin. Dall, 1898, p. 687.
Crassostrea virginica Gmelin. [*sic*] Abbott, 1954, p. 375, pl. 28, fig. a.
Crassostrea virginica (Gmelin). Richards, 1962, p. 55, pl. 4, figs. 5–7.

Diagnosis.—Shell large, thick, strong, irregular, generally longer than wide. Sculpture of low, broad, radial ribs with wider interspaces. Shell outline very variable. Ventral valve concave, deeply cupped. Upper valve much flatter.

Measurements.—Length, 44.5 mm; height, 75.0 mm.

Distribution.—Upper Pliocene: Florida; Pleistocene: Massachusetts to Florida and Texas, Panama; Recent: New Brunswick to Gulf of Mexico.

Occurrence in this study.—Localities 17b, 17c, 17d, 17e, 17f, 18a, 18b, 18c, 18d, 18e, 19a, 20a, 22a, 22b, 22c, 26a, 27.

Type information.—Holotype: unknown. Figured hypotype: USNM 218179.

Discussion.—Reworked and transported specimens of this species are common and widespread in the Virginia Pleistocene, but it has been found in place at only two localities (22c, 27). Dall (1898) lists numerous synonyms which are not repeated here. The variability of shell outline is due to the effects of substrate, age, current direction and strength, and to population crowding.

Family **LUCINIDAE** Fleming, 1828

Genus **LINGA** Gregorio, 1884

Linga amiantus (Dall, 1901)

Phacoides (*Bellucina*) *amiantus* Dall, 1901, p. 826, pl. 39, fig. 10.
Lucina amiantus Dall. [*sic*] Abbott, 1954, p. 385, fig. 78c.
Lucina amiantus (Dall). Richards, 1962, p. 61, pl. 7, figs. 18–19.
Linga amiantus (Dall). Abbott, 1974, p. 458, fig. 5285.

Diagnosis.—Shell small, thin, circular, compressed. Radial sculpture of low, undulatory ribs with narrow interspaces. Ribs crossed by fine concentric lines. Beaks low, central, prosogyrate.

Distribution.—Pleistocene: Virginia to South Carolina and Louisiana; Recent: North Carolina to the West Indies, Brazil.

Occurrence in this study.—Locality 17c.

Type information.—Holotype: USNM 60948.

Discussion.—This species resembles *Codakia costata* (d'Orbigny, 1842), but is lighter and much less inflated. A single poorly preserved specimen was found.

Genus **PARVILUCINA** Dall, 1901

Parvilucina multilineata (Tuomey and Holmes, 1856)
Plate 5, figures 15, 19

Lucina multilineata Tuomey and Holmes, 1856, p. 61, pl. 18, figs. 16–17.
Phacoides (*Parvilucina*) *crenella* Dall, 1901, pp. 810, 825, pl. 39, fig. 2.
Phacoides (*Parvilucina*) *multilineatus* (Tuomey and Holmes). Dall, 1903, p. 1384.
Phacoides (*Parvilucina*) *multilineatus* (Tuomey and Holmes). Gardner, 1943, p. 78, pl. 13, figs. 34–37.
Lucina multilineata Tuomey and Holmes. Abbott, 1954, p. 386, fig. 78f.
Lucina multilineata Tuomey and Holmes. Richards, 1962, p. 61, pl. 7, figs. 20–21.
Parvilucina multilineata (Tuomey and Holmes). Abbott, 1974, p. 459, fig. 5290.

Diagnosis.—Shell very small, circular, inflated. Sculpture of fine radial threads crossed by concentric threads of equal strength and spacing. Beaks high, prosogyrate. Lunule large, depressed. Interior ventral margin crenulate.

Measurements.—Length, 4.5 mm; height, 4.5 mm.

Distribution.—Lower Pliocene: Virginia to Florida; Upper Pliocene: North Carolina to Florida; Pleistocene: Maryland to Florida, Alabama and Louisiana; Recent: Virginia to Florida.

Occurrence in this study.—Localities 17c, 18a, 18b, 18d, 18e, 19a, 21a, 26a.

Type information.—Holotype: AMNH (missing). Figured hypotype: USNM 218186.

Genus **CODAKIA** Scopoli, 1777

Codakia costata (d'Orbigny, 1842)
Plate 5, figures 16, 20

Lucina costata d'Orbigny, 1842, pl. 27, figs. 40–41.
Codakia costata d'Orbigny. [*sic*] Abbott, 1954, p. 390.
Codakia costata (d'Orbigny). Richards, 1962, p. 62, pl. 7, figs. 26–27.
Codakia costata (d'Orbigny). Abbott, 1968, p. 222, fig. 6.

Diagnosis.—Shell very small, circular, well inflated, strong. Sculpture of 12 to 14 broad, radial ribs with narrower interspaces: ribs and interspaces crossed by coarse concentric threads. Beaks fairly low, prosogyrate.

Measurements.—Length, 6.7 mm; height, 7.8 mm.

Distribution.—Pleistocene: Virginia to South Carolina and Florida; Recent: North Carolina to Brazil.

Occurrence in this study.—Locality 18e.

Type information.— Holotype: BMNH 1854.12.4.-765. Figured hypotype: USNM 218169.

Genus **DIVALINGA** Chavan, 1951

Divalinga quadrisulcata (d'Orbigny, 1842)
Plate 5, figures 17, 18

Lucina quadrisulcata d'Orbigny, 1842, pl. 27, figs. 40–41.
Divaricella quadrisulcata (d'Orbigny). Dall, 1903, p. 1389, pl. 51, fig. 1.
Divaricella quadrisulcata d'Orbigny. [*sic*] Abbott, 1954, p. 391, pl. 30, fig. m.
Divaricella quadrisulcata (d'Orbigny). Richards, 1962, p. 62, pl. 7, figs. 28–29.
Divalinga quadrisulcata (d'Orbigny). Keen, 1971, p. 125.
Divaricella quadrisulcata (d'Orbigny). Abbott, 1974, p. 462.

Diagnosis.—Shell small, circular, well inflated, thin but strong. Sculpture of gently-curving parallel chevrons centered a little posterior of the midline of the shell. Cardinal teeth small. Beaks very low, central, directed perpendicular to the hingeline.

Measurements.—Length, 18.0 mm; height, 16.5 mm.

Distribution.—Miocene (?): Maryland and Virginia;

Lower Pliocene: Virginia to Florida and Texas; Upper Pliocene: Florida; Pleistocene: New Jersey to Florida and Texas; Recent: Massachusetts to Brazil.

Occurrence in this study.—Localities 15, 17b, 17c, 17d, 18b, 18d, 19a, 21a, 26a.

Type information.—Syntype: BMNH 1854.12.4.764. Figured hypotype: USNM 218187.

Family **UNGULINIDAE** Adams and Adams, 1857

Genus **DIPLODONTA** Bronn, 1831

Diplodonta punctata (Say, 1822)
Plate 6, figures 1, 5

Amphidesma punctata Say, 1822, p. 308
Diplodonta punctata (Say). Dall, 1900, p. 1187.
Diplodonta punctata Say. [*sic*] Abbott, 1954, p. 383.
Diplodonta punctata (Say). Richards, 1962, p. 61, pl. 7, figs. 10–11, 35–36.

Diagnosis.—Shell small, circular, inflated, thin. Sculpture of growth lines and microscopic pits. Beaks low, central. Juveniles are more compressed.

Measurements.—Length, 7.8 mm; height, 7.3 mm.

Distribution.—Pleistocene: New Jersey to Florida; Recent: North Carolina to Brazil.

Occurrence in this study.—Localities 17c, 18b, 18d, 18e, 19a, 20b, 21a, 26a.

Type information.—Holotype ANSP (missing). Figured hypotype: USNM 218188.

Family **KELLIIDAE** Forbes and Hanley, 1848

Genus **BORNIA** Philippi, 1836

Bornia longipes (Stimpson, 1855)
Plate 6, figures 2, 6

Lepton longipes Stimpson, 1855, p. 111.
Bornia longipes Stimpson. [*sic*] Abbott, 1954, p. 396, fig. 80c.
Bornia longipes (Stimpson). Richards, 1962, p. 62, pl. 7, figs. 30–31.

Diagnosis.—Shell reaching 10 mm, ovate-triangular, moderately inflated; beaks central, small; cardinal teeth weakly developed, laterals short but strong; muscle scars elongate, connected by a loop-shaped pallial line. Exterior smooth, polished, glistening.

Measurements.—Length, 9.5 mm; height, 9.0 mm.

Distribution.—Pleistocene: Virginia; Recent: North and South Carolina.

Occurrence in this study.—Localities 7, 17b, 17c, 17d, 17e, 17f, 18b, 18d, 19a, 20a, 22a, 22b, 26a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218189.

Discussion.—This species closely resembles *B. triangulata* Dall, 1900, of the underlying Pliocene, but may be readily distinguished by its more rounded dorsal slopes and consequently by its more oval rather than triangular form.

Family **MONTACUTIDAE** Clark, 1855

Genus **ALIGENA** Lea, 1843

Aligena elevata (Stimpson, 1851)
Plate 6, figures 3, 7

Montacuta bidentata Gould, 1841, p. 59 (not of Turton, 1822).
Montacuta elevata Stimpson, 1851, p. 16.
Aligena elevata (Stimpson). Richards, 1962, p. 62, pl. 7, figs. 40–41.
Aligena elevata (Stimpson). Wass, 1965, p. 22.

Diagnosis.—Shell less than 5 mm long, oval, thin, very inflated; beaks central, bidentate cardinals; muscle scars small, connected by a loop-shaped pallial line. Exterior with very fine lines of growth.

Measurements.—Length, 3.0 mm; height, 2.5 mm.

Distribution.—Pleistocene: New Jersey to South Carolina; Recent: Massachusetts to North Carolina.

Occurrence in this study.—Localities 18b, 19a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218190.

Discussion.—This minute species is rare but undoubtedly overlooked in the Pleistocene. It is commensal with a species of polychaete worm in the Chesapeake Bay (Wass, 1965, p. 22).

Genus **MYSELLA** Angas, 1877

Mysella planulata (Stimpson, 1851)
Plate 6, figures 4, 8

Kellia planulata Stimpson, 1851, p. 17.
Rochefortia planulata (Stimpson). Dall, 1900, p. 1161, pl. 45, fig. 7.
Mysella planulata Stimpson. [*sic*] Abbott, 1954, p. 395.
Mysella planulata (Stimpson). Richards, 1962, p. 62, pl. 7, fig. 47.
not *Mysella bidentata* (Montagu). Wass, 1972, p. 123.

Diagnosis.—Shell very small, thin, quadrate, smooth. Beaks triangular, fairly high, posteriorly placed. Hinge with two thin lateral teeth and a large V-shaped cavity under the beak.

Measurements.—Length, 3.4 mm; height, 3.4 mm.

Distribution.—Upper Pliocene: Florida; Pleistocene: Maryland to Florida; Recent: Nova Scotia to Texas and the West Indies.

Occurrence in this study.—Localities 18b, 18d, 19a, 22b, 22c.

Type information.—Holotype: unknown. Figured hypotype: USNM 218191.

Discussion.—Keen (1971, p. 140) places the genus *Rochefortia* Vélain, 1877 in synonymy with *Mysella*, but Morrison (oral commun., 1979) maintains that properly defined, *Mysella* has only one cardinal tooth on the right valve, *Rochefortia* has two, and that this constitutes a valid generic character. If this proves true, *Mysella bidentata* (Montagu, 1803) (the type species of *Mysella*) cannot be conspecific with *Rochefortia planulata* as stated by Jenner (in Wass, 1972). A number of mysellids have been described from the underlying Tertiary (Dall, 1900; Gardner, 1943), none of which approach *M. planulata* in its lack of inflation or in its rectangular outline.

Family **CARDITIDAE** Fleming, 1820

Genus **PLEUROMERIS** Conrad, 1867

Pleuromeris tridentata (Say, 1826)
Plate 5, figures 13, 14

Venericardia tridentata Say, 1826, p. 216.
Venericardia (*Pleuromeris*) *tridentata* Say. Dall, 1903, p. 1433.
Glans (*Pleuromeris*) *tridentata* (Say). Gardner, 1943, p. 70.
Venericardia tridentata Say. [*sic*] Abbott, 1954, p. 380.
Venericardia tridentata (Say). Richards, 1962, p. 60, pl. 7, fig. 3.
Pleuromeris tridentata (Say). Abbott, 1974, p. 477, fig. 589.

Diagnosis.—Shell small, triangular, very heavy. Sculpture of nine to 10 strong radial ribs with narrower interspaces. Ribs crossed by coarse, concentric threads. Interior ventral margin coarsely denticulate. Hinge teeth very large.

Measurements.—Length, 8.5 mm; height, 8.0 mm.

Distribution.—Lower Pliocene: Virginia to Florida; Upper Pliocene: North Carolina to Florida; Pleistocene: New Jersey to Florida; Recent: Virginia to Florida.

Occurrence in this study.—Localities 7, 15, 17c, 18a, 18d, 19a, 20a, 21a, 26a.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218185.

Genus **CYCLOCARDIA** Conrad, 1867

Cyclocardia borealis (Conrad, 1831)
Plate 5, figures 11, 12

Cardita borealis Conrad, 1831, p. 39, pl. 8, fig. 1.
Venericardia (*Cyclocardia*) *borealis* (Conrad). Dall, 1903, p. 1431.
Venericardia borealis Conrad. [*sic*] Abbott, 1954, p. 379, pl. 28, fig. 1.
Venericardia borealis (Conrad). Richards, 1962, p. 60, pl. 6, figs. 29–30.
Cyclocardia borealis (Conrad). Abbott, 1974, p. 478, fig. 5493.

Diagnosis.—Shell of moderate size, circular, very heavy. Sculpture of about 20 gently-curved radial ribs with subequal interspaces. Ribs crossed by concentric growth lines. Interior ventral margin denticulate. Beaks high, round, prosogyrate. Hinge teeth large, heavy.

Measurements.—Length, 22.5 mm; height, 24.5 mm.

Distribution.—Miocene: (as *C. granulata*) New Jersey to Virginia, Florida?; Lower Pliocene: Virginia to Florida; Upper Pliocene: North and South Carolina; Pleistocene: (as *C. borealis*) Labrador to Virginia; Recent: Labrador to North Carolina (deep water).

Occurrence in this study.—Localities 17b, 21a, 23, 27.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218184.

Discussion.—*C. borealis* has been equated with the Mio-Pliocene *C. granulata* (Say, 1824) by some workers while others consider them distinct (Dall, 1903). Should the two prove identical, *C. granulata* has priority. There would be little question about uniting them were it not for the fact that *C. granulata* occurs abundantly in assemblages indicating warm-temperate to subtropical conditions in Mio-Pliocene deposits from New Jersey to Florida, but *C. borealis* is strictly cold water in the Pleistocene and Recent. Possibly, *C. granulata* was cosmopolitan in the Mio-Pliocene with cold- and warm-water populations, the latter becoming extinct near the Plio-Pleistocene boundary. Such a proposal is speculative because no east coast cold-water Mio-Pliocene coastal deposits have been found. Also, some parameter other than temperature might be controlling distribution. Assuming a temperature control, one might expect that greater stress would be placed on boreal populations; the more stable warm-water assemblages by contrast should be more persistent. However, Bretsky's Paleozoic stability–extinction studies suggest that assemblages from more uniform environments experience more, and more frequent, extinctions than those from environments that experience periodic stress (Bretsky, 1968, pp. 45–59). At any rate, we cannot find any consistent basis for separating the two species on shell morphology. Ultimate resolution of the question may rest in a thorough multivariant analysis of large populations through time and space. *C. borealis* is very rare in the Virginia Pleistocene.

Family **ASTARTIDAE** d'Orbigny, 1845

Genus **ASTARTE** Sowerby, 1816

Astarte castanea (Say, 1822)
Plate 5, figures 4, 7

Venus castaneus Say, 1822, p. 273.
Astarte castanea Say. [*sic*] Abbott, 1954, p. 376, pl. 28, fig. s.
Astarte castanea (Say). Richards, 1962, p. 59, pl. 6, figs. 19–20.

Diagnosis.—Shell of moderate size, triangular, solid, compressed, smooth. Ventral margin evenly rounded. Sculpture of concentric growth lines only. Beaks high, large, triangular. Cardinal teeth very heavy. Interior ventral margin crenulate.

Measurements.—Length, 23.0 mm; height, 24.5 mm.

Distribution.—Pleistocene: Maine to Virginia; Recent: Nova Scotia to Long Island in shallow water, to North Carolina 50 to 80 m (Porter, 1974).

Occurrence in this study.—Localities 17b, 23.

Type information.—Holotype: ANSP 55306. Figured hypotype: USNM 218182.

Discussion.—This typically cold-water species was abundant in beach replenishment dredgings at 17th Street and ocean front, Virginia Beach, Virginia, but is rare or absent elsewhere.

Family **CRASSATELLIDAE** Férussac, 1822

Genus **CRASSINELLA** Guppy, 1874

Crassinella lunulata (Conrad, 1834)
Plate 5, figures 9, 10

Astarte lunulata Conrad, 1834, p. 133.
Gouldia lunulata (Conrad). Conrad, 1862, p. 578.
Crassatellites (*Crassinella*) *lunulatus* (Conrad). Dall, 1903, pp. 1477–1478.
Crassinella lunulata (Conrad). Gardner, 1943, pp. 62–63, pl. 19, fig. 30.
Crassinella lunulata (Conrad). Olsson and Harbison, 1953, p. 72.
Crassinella lunulata Conrad. [*sic*] Abbott, 1954, p. 377, fig. 28k.
Crassinella lunulata (Conrad). Richards, 1962, pp. 59–60, pl. 6, figs. 27–28.
Crassinella lunulata (Conrad). Abbott, 1968, p. 216, fig. 5.

Diagnosis.—Shell small to very small, triangular, thin but strong. Sculpture of thin concentric lamellae; microsculpture of a granular "snake-skin" pattern. Beaks small, pointed, central, opisthogyrate. Interior ventral margin smooth.

Measurements.—Length, 5.0 mm; height, 4.8 mm.

Distribution.—Miocene: Maryland; Lower Pliocene: Virginia to Florida; Upper Pliocene: North Carolina to Florida; Pleistocene: Virginia to Florida and Louisiana; Recent: North Carolina to the West Indies, Brazil.

Occurrence in this study.—Localities 15, 17b, 17c, 17d, 18a, 18b, 18d, 18e, 19a, 20a, 21a, 22a, 26a.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218183.

Discussion.—Much confusion exists in the literature over this small and widespread species. Conrad's type is Pliocene from the James River of Virginia. Dall (1903) states that *C. lunulata* should be used for fossil, *C. mactracea* (Linsley, 1845) for Recent specimens, but in discussing *C. acutus* Dall, 1903, he states (Dall, 1903, p. 1479): "Recent forms of the Atlantic coast may all be referred to *C. lunulatus* Conrad, though the varieties are numerous." Gardner (1943), and Olsson and Harbison (1953) following Dall's initial opinion, cite no Recent distribution; the latter authors further state that Recent Atlantic coast specimens should be referred to *C. mactracea.* Abbott (1954), distinguishes in the Recent between a southern *C. lunulata* and a northern *C. mactracea,* pointing out differences of shell character, which were subsequently better defined and excellently illustrated in his 1968 edition. The most diagnostic of the several characters is the relative width of the lunule and escutcheon: in *C. lunulata* these structures are of approximately the same width, whereas in *C. mactracea* the lunule is considerably wider than the escutcheon. Richards (1962) follows Abbott in the division of the Recent species, but he attributes to *C. lunulata* a northern range. Abbott (1974) however, places *C. mactracea* in synonymy with *C. lunulata.* The question of synonymy, therefore, remains unresolved.

Family **CARDIIDAE** Oken, 1815

Genus **DINOCARDIUM** Dall, 1900

Dinocardium robustum (Lightfoot, 1786)
Plate 6, figures 9, 12

Cardium magnum Born, 1780, p. 46, pl. 3, fig. 5 (not of Linné, 1758).
Cardium robustum Lightfoot, 1786, p. 58.
Dinocardium robustum (Solander). Dall, 1900, p. 1074.
Dinocardium robustum (Solander). Clench and Smith, 1944, p. 9, pl. 6.
Dinocardium robustum Solander. [*sic*] Abbott, 1954, p. 401, pl. 32, fig. a.
Dinocardium robustum (Solander). Richards, 1962, p. 63, pl. 8, figs. 6–7.
Dinocardium robustum (Lightfoot). Rehder, 1967, p. 12.

Diagnosis.—Shell very large, obliquely oval, thin but strong. Sculpture of about 30 flat, radial ribs with deep, narrow interspaces. Concentric sculpture of fine threads best seen in the interspaces. Beaks large, high, well rounded. Interior ventral margin denticulate.

Measurements.—Length, 44.0 mm; height, 44.0 mm.

Distribution.—Lower Pliocene: North Carolina and Texas; Upper Pliocene: North Carolina to Florida; Pleistocene: Virginia to Florida and Louisiana; Recent: Virginia to North Florida and Texas.

Occurrence in this study.—Localities 17b, 17c, 17e, 18a, 18b, 18d, 19a, 21a, 22a, 26a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218192.

Discussion.—*Dinocardium robustum* can be distinguished from the Pliocene species *Planicardium acutilaqueatum* (Conrad, 1839) by the latter's V-shaped rather than flattened ribs, and from the Pliocene species *P. virginianum* (Conrad, 1839) by the latter's relatively narrower shell. Both of these Pliocene species additionally can be separated by their *Cerastoderma*-like hinge.

Family **MACTRIDAE** Lamarck, 1809

Genus **SPISULA** Gray, 1837

Spisula solidissima (Dillwyn, 1817)
Plate 7, figures 13,14

Mactra solidissima Dillwyn, 1817, p. 140.
Spisula (*Hemimactra*) *solidissima* (Dillwyn). Dall, 1898, p. 878.
Spisula solidissima Dillwyn. [*sic*] Abbott, 1954, p. 446, pl. 32, fig. p.
Spisula solidissima (Dillwyn). Richards, 1962, p. 69, pl. 11, figs. 17, 20, 21.
Spisula solidissima (Dillwyn). Castagna and Chanley, 1973, pp. 80–81, 90–91.

Diagnosis.—Shell very large, ovate-triangular, thin but strong, smooth. Surface with growth lines only. Hinge with strong, thin lateral teeth; chondrophore pit large, broadly triangular. Beaks high, rounded, central.

Measurements.—Length, 72.5 mm; height, 51.5 mm.

Distribution.—Pleistocene: Maine to South Carolina; Recent: Labrador to Gulf of Mexico.

Occurrence in this study.—Localities 15, 17a, 17b (often articulated valves, in place), 17c, 18a, 18b, 18d, 19a, 20a, 22a, 25a, 26a, 27.

Type information.—Holotype: unknown. Figured hypotype: USNM 218201.

Discussion.—Called the "surf clam" because of the abundance of shells along Atlantic coast beaches, *S. solidissima* prefers more stable conditions offshore where commercial quantities are harvested, especially off New Jersey. Castagna and Chanley (1973) have shown that the species is tolerant of salinities down to 15‰ but never occurs naturally below 28‰. They suggest that palatability rather than salinity controls the species distribution because "when larvae colonize inshore areas they rarely develop beyond the juvenile stage because they are subject to intense predation by a variety of crabs, carnivorous gastropods and bottom-feeding fish."

Numerous species of *Spisula* abound in the Pliocene (see Gardner, 1943, or Vokes, 1957), none of which approach *S. solidissima* in size or shell thickness.

Genus **MULINIA** Gray, 1837

Mulinia lateralis (Say, 1822)
Plate 7, figures 7, 10

Mactra lateralis Say, 1822, p. 309.
Mulinia lateralis (Say). Dall, 1898, pp. 901–902.
Mulinia lateralis Say. [*sic*] Abbott, 1954, p. 449, pl. 32, fig. o.
Mulinia lateralis (Say). Richards, 1962, p. 69, pl. 11, figs. 22–23.

Diagnosis.—Shell small, ovate-triangular, attenuated posteriorly, thin but strong. Surface smooth except for growth lines and a low radial ridge defining the posterior slope. Hinge proportionally heavy, with a small, narrowly triangular chondrophore.

Measurements.—Length, 17.0 mm; height, 12.0 mm.

Distribution.—Lower Pliocene: North Carolina to Texas; Upper Pliocene: South Carolina to Florida; Pleistocene: Bay of Fundy, New York to Georgia, Louisiana, and Texas; Recent: Maine to North Florida and Texas.

Occurrence in this study.—Localities 7, 12, 15, 17c, 17d, 17e, 17f, 18b, 18d, 18e, 19a, 20b, 21a, 22b, 25a, 26a, 27, 29, 30.

Type information.—Neotype: ANSP 52663. Figured hypotype: USNM 218198.

Discussion.—*M. lateralis,* one of the most widespread species in the Virginia Pleistocene, is characteristic of estuaries, bays, and littoral shelf environments. *M. congesta* (Conrad, 1833) of the Yorktown Pliocene tends to be a larger, heavier shell with more strongly developed lateral teeth.

Genus **RANGIA** Desmoulins, 1832

Rangia cuneata (Sowerby, 1831)
Plate 7, figures 9, 12

Gnathodon cuneata Sowerby, 1831, pl. 36, figs. 1–7.
Rangia cuneata (Grey). Dall, 1898, p. 904.
Rangia cuneata Grey. [*sic*] Abbott, 1954, p. 450, figs. 91a–b.
Rangia cuneata (Grey). Richards, 1962, p. 69, pl. 12, fig. 16.

Diagnosis.—Shell large, heavy, oval. Surface smooth. Hinge with long, heavy, curved lateral teeth. Chondrophore large, triangular, deep.

Measurements.—Length, 23.5 mm; height, 21.0 mm.

Distribution.—Upper Pliocene: North Carolina; Pleistocene: Maryland to Florida, Louisiana, and Texas; Recent: Maryland to North Florida and Texas.

Occurrence in this study.—Localities 1, 5, 17b, 17c, 17e, 17f, 18a, 18b, 18d, 18e, 20a, 20b, 22a, 22b, 23, 27, 30.

Type information.—Holotype: unknown. Figured hypotype: USNM 218200.

Discussion.—Long known from a very successful relict population in the estuaries of the Gulf of Mexico, this species has recently re-established itself along the Atlantic Coast. The Potomac River seems to be its current northern limit, a distribution which coincides with its maximum Pleistocene distribution. In the James River, it shows a wide range of salinity tolerance but prefers a range of three to 10 parts per thousand. The Pleistocene specimens in our collections are small, abraded or broken single valves showing considerable transport. *R. clathrodonta* (Conrad, 1833) of the Yorktown Pliocene has a straighter posterior slope, straight posterior laterals, and a relatively larger ligamental pit.

Genus **RAETA** Gray, 1853

Raeta plicatella (Lamarck, 1818)
Plate 7, figures 8, 11

Lutraria plicatella Lamarck, 1818, p. 470.
Lutraria canaliculata Say, 1822, p. 310.
Labiosa (*Raeta*) *canaliculata* (Say). Dall, 1898, p. 907.
Labiosa plicatella Lamarck. [*sic*] Abbott, 1954, p. 449, pl. 32, fig. q.
Labiosa plicatella (Lamarck). Richards, 1962, p. 69, pl. 12, fig. 9.
Raeta plicatella (Lamarck). Olsson and Petit, 1964, pp. 533–534.
Raeta plicatella (Lamarck). Keen, 1971, p. 207.

Diagnosis.—Shell large, very thin, ovate-triangular, attenuated posteriorly. Sculpture of close-set concentric undulations equally visible on the inside of the shell. Hinge small; lateral teeth thin; anterior lateral quite short.

Measurements.—Length, 52.0 mm; height, 39.0 mm.

Distribution.—Lower Pliocene: Texas?; Pleistocene: New Jersey to Florida, Louisiana and Texas; Recent: New Jersey to Argentina.

Occurrence in this study.—Localities 17e, 17f, 18e.

Type information.—Holotype: unknown. Figured hypotype: USNM 218199.

Discussion.—Because our Pleistocene specimens are fragmented, a Recent specimen is figured. *Raeta alta* Conrad, 1875, of the Yorktown Pliocene is a much heavier and taller shell with more subdued undulatory sculpture. *R. undulata* (Gould, 1851), Recent from California to Peru, has been found in the Pliocene Pinecrest beds of South Florida (Olsson and Petit, 1964) and in the Waccamaw of South Carolina. It differs from both the above species in its centrally-placed beaks and in details of sculpture.

Family **SOLENIDAE** Lamarck, 1809

Genus **ENSIS** Schumacher, 1817

Ensis directus (Conrad, 1844)

Plate 9, figures 7, 8

Solen directus Conrad, 1844, p. 325.
Ensis directus (Conrad). Dall, 1900, p. 954.
Ensis directus Conrad. [*sic*] Abbott, 1954, p. 443, pl. 30, fig. k.
Ensis directus (Conrad). Richards, 1962, p. 68, pl. 11, fig. 8.

Diagnosis.—Shell large, thin, rectangular, exceedingly elongate, smooth.

Measurements.—Length, 140.5 mm; height, 22.5 mm.

Distribution.—Miocene: Maryland, Florida?; Lower Pliocene: Virginia to Florida; Upper Pliocene: North Carolina to Florida; Pleistocene: Maine to Florida and the Gulf States; Recent: Labrador to South Carolina.

Occurrence in this study.—Localities 12, 13, 15, 17b, 17c, 17d, 18a, 18b, 18c, 18d, 18e, 19a, 20a, 21a, 22a, 22b, 25a, 26a, 27.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218213.

Discussion.—Two additional species of *Ensis* can be found in the Virginia Pliocene. *E. ensiformis* (Conrad, 1844) is a smaller, curved, more elongate species resembling the recent *E. minor* Dall, 1900. *E. schmidti* Olsson, 1914, is a relatively broader and shorter species with a rounded posterior margin.

Family **TELLINIDAE** Blainville, 1814

Genus **TELLINA** Linné, 1758

Tellina agilis Stimpson, 1858

Plate 8, figures 1, 4

Tellina tenera Say, 1822, p. 303 (not of Schrank, 1803).
Tellina agilis Stimpson, 1858, vol. 25, p. 125.
Tellina agilis Stimpson. Abbott, 1954, p. 422, pl. 30, fig. x; fig. 86f.
Tellina agilis Stimpson. Richards, 1962, p. 66, pl. 10, figs. 10–11.

Diagnosis.—Shell small, thin, compressed, attenuated posteriorly. Surface sculptured with low, thin, flat lines. Posterior slope straight to slightly convex.

Measurements.—Length, 15.0 mm; height, 8.0 mm.

Distribution.—Pleistocene: Massachusetts to South Carolina and Louisiana; Recent: Gulf of St. Lawrence to Georgia.

Occurrence in this study.—Localities 15, 17c.

Type information.—Syntype: ANSP 52446. Figured hypotype: USNM 218204.

Discussion.—Pleistocene specimens of *T. agilis* are very rare. *T. texana* Dall, 1900, the common species of *Tellina* in our collections, has a pallial sinus that nearly touches the anterior adductor muscle scar; smoother, more irregular concentric sculpture; and two grooves running from the posterior adductor scar to the ventral margin of the shell. *T. versicolor* Dekay, 1843, may be present but thus far undetected; it is smoother, more inflated, and has a much narrower pallial sinus. It is common in the Recent and has been reported as a fossil from Florida. Two Yorktown Pliocene species should also be considered. *T. declivis* Conrad, 1834, is sculptured much like *T. texana*, but lacks the internal grooving and leaves a greater gap between the pallial sinus and the anterior adductor than any of the above. *T. dupliniana* Dall, 1900, is a rare form with a much more abrupt posterior margin. More extensive discussion can be found in Gardner (1943), Abbott (1954, 1968), and Boss (1968).

Tellina alternata Say, 1822

Plate 8, figures 3, 6

Tellina alternata Say, 1822, p. 275.
Tellina (*Eurytellina*) *alternata* Say. Dall, 1900, p. 1029.
Tellina alternata Say. Abbott, 1954, p. 427, pl. 40, fig. n.
Tellina alternata Say. Richards, 1962, p. 66, pl. 10, fig. 12.

Diagnosis.—Shell large, thin, compressed, attenuated posteriorly. Sculpture of low, flat, concentric cords. Posterior slope straight.

Measurements.—Length, 40.0 mm; height, 23.5 mm.

Distribution.—Lower Pliocene: Florida; Upper Pliocene: North Carolina to Florida; Pleistocene: Virginia to Florida and Louisiana, Panama; Recent: North Carolina to Florida, Gulf States, and Cuba.

Occurrence in this study.—Locality 18e.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218202.

Tellina texana Dall, 1900
Plate 8, figures 2, 5

Tellina polita Say, 1822, p. 276 (not of Poli, 1795; Spengler, 1798; Pultney, 1799; or Sowerby, 1825).
Tellina texana Dall, 1900, p. 313.
Tellina sayi "Deshayes" ms. Dall, 1900, p. 1304.
Tellina sayi Dall. Gardner, 1943, p. 55, pl. 17, fig. 4.
Tellina texana Dall. Abbott, 1954, p. 424.
Tellina texana Dall. Richards, 1962, p. 66, pl. 10, figs. 8–9.

Diagnosis.—Shell very small, thin, solid, compressed. Concentric sculpture of very low, flattened threads and cords with shallow to indistinct, incised interspaces. Interior of shell with two radial grooves passing from beak to posteroventral margin.

Measurements.—Length, 9.9 mm; height, 5.8 mm.

Distribution.—Upper Pliocene: North Carolina to Florida; Pleistocene: Virginia to South Carolina; Recent: New Jersey to Florida, Texas and Cuba.

Occurrence in this study.—Localities 17b, 17c, 17d, 18a, 18b, 18d, 18e, 19a, 20b, 21a, 22a, 22b, 26a, 27.

Type information.—Holotype: USNM 125539. Figured hypotype: USNM 218203.

Discussion.—This species is often confused with *T. agilis* Stimpson, 1858, but can be immediately separated by the two internal grooves running from the posterior adductor scar to the ventral margin of the shell.

Genus **MACOMA** Leach, 1817

Macoma balthica (Linné, 1758)
Plate 8, figures 7, 8

Tellina balthica Linné, 1758, p. 667.
Macoma balthica (Linné). Dall, 1900, p. 1051.
Macoma balthica Linné. [*sic*] Abbott, 1954, p. 431, fig. 88g.
Macoma balthica (Linné). Richards, 1962, p. 66, pl. 10, figs. 15–16.
Macoma balthica (Linné). Durham and MacNeil, 1967, p. 330.

Diagnosis.—Shell of moderate size, thin, inflated, ovate. Surface smooth save for lines of growth. Hinge small; lateral teeth lacking.

Measurements.—Length, 27.5 mm; height, 22.5 mm.

Distribution.—Upper Pliocene: North Carolina; Pleistocene: North Pacific; James Bay to South Carolina, Great Britain and the Netherlands; Recent: Arctic to California, Georgia, and Europe.

Occurrence in this study.—Localities 9, 17f, 18e, 20b, 21a.

Type information.—Holotype: Linnaean Society (uncatalogued). Figured hypotype: USNM 218205.

Macoma constricta (Bruguière, 1792)
Plate 8, figures 9, 12

Solen constrictus Bruguière, 1792, p. 126.
Macoma constricta (Bruguière). Dall, 1900, p. 1050.
Macoma constricta Bruguière. [*sic*] Abbott, 1954, p. 432.
Macoma constricta (Bruguière). Richards, 1962, p. 67, pl. 10, figs. 20–21.

Diagnosis.—Shell of moderate size, thin, somewhat compressed, attenuated and truncated posteriorly. Surface smooth save for lines of growth and a few variably-placed, thin radial lines. Somewhat irregular in outline.

Measurements.—Length, 54.0 mm; height, 36.5 mm.

Distribution.—Upper Pliocene: Florida; Pleistocene: Virginia to Florida and Louisiana; Recent: North Carolina to Texas and the Caribbean.

Occurrence in this study.—Localities 17f, 18e, 20b.

Type information.—Holotype: unknown. Figured hypotype: USNM 218206.

Family **DONACIDAE** Fleming, 1828

Genus **DONAX** Linné, 1758

Donax parvula Philippi, 1849
Plate 8, figures 13, 14

Donax parvula Philippi, 1849, p. 146.
Donax obesa (d'Orbigny). Dall, 1889, p. 58 (in part; not *D. obesa* d'Orbigny, 1846).
Donax tumidus (Philippi). Johnson, 1934, p. 54 (in part; not *D. tumida* of Philippi, 1849).
Donax parvula Philippi. Morrison, 1971, pp. 552–554.

Diagnosis.—Shell small, thick, solid, wedge-shaped. Posterior slope blunt, abrupt. Sculpture of faint radiating lines, stronger in abraded areas. Interior ventral margin weakly crenulate. Hinge with the notched nympha typical of the genus.

Measurements.—Length, 8.1 mm; height, 5.2 mm.

Distribution.—Upper Pliocene: North Carolina?; Pleistocene: Virginia; Recent: Ocracoke, North Carolina to St. Lucie Park, Florida.

Occurrence in this study.—Locality 17c.

Type information.—Holotype: unknown. Figured hypotype: USNM 218208.

Discussion.—It is likely that most southern records of Pleistocene *D. fossor* Say, 1822, belong to this little-recognized but distinct species. Gardner (1943, pl. 23, figs. 2, 11) figures as "*D. fossor*", a Waccamaw specimen very similar to *D. parvula*.

Donax roemeri protracta (Conrad, 1849)
Plate 8, figures 10, 11

Donax variabilis Say, 1822, p. 305 (not of Schumacher, 1817).
Donax protracta Conrad, 1849, pp. 208, 280, pl. 39, fig. 8.
Donax variabilis (Say). Dall, 1900, p. 969.
Donax variabilis Say. [*sic*] Abbott, 1954, p. 437, pl. 30, fig. r.
Donax variabilis (Say). Richards, 1962, p. 68, pl. 10, figs. 33–35.
Donax roemeri protracta (Conrad). Morrison, 1971, pp. 550–552.

Diagnosis.—Shell small, thick, solid, wedge-shaped; smooth. Posterior end produced. Interior ventral margin crenulate.

Measurements.—Length, 8.6 mm; height, 4.5 mm.

Distribution.—Pleistocene: Virginia to Georgia, Louisiana?; Recent: Virginia Beach (occasional), Cape Hatteras to Florida and Mississippi.

Occurrence in this study.—Localities 10, 17c, 18b, 18d, 19a, 26a.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218207.

Discussion.—This species has been referred to Say's preoccupied designation by most authors. Morrison's excellent monograph on the Western Atlantic species of *Donax* fully discusses the life cycles, synonymies, and Recent distribution of this and the species previously discussed here. He states that this species can be distinguished by the presence of strong radial striation on its posterior slope only, and by the abruptness of its posterior ridge. Pleistocene records have not been reexamined in terms of Morrison's criteria and are, therefore, reported with less than full confidence.

Family **SEMELIDAE** Stoliczka, 1870

Genus **SEMELE** Schumacher, 1817

Semele cf. **S. purpurascens** (Gmelin, 1791)
Plate 8, figures 19, 20

Venus purpurascens Gmelin, 1791, p. 3288, no. 91.
Semele purpurascens (Gmelin). Dall, 1900, p. 993.
Semele purpurascens Gmelin. [*sic*] Abbott, 1954, p. 435, pl. 40, fig. b.

Diagnosis.—Shell of medium size, thin, oval, compressed. Sculpture of growth lines crossed by oblique concentric, microscopic lines.

Measurements.—Length, 9.7 mm; height, 8.2 mm.

Distribution.—Upper Pliocene: Florida; Pleistocene: Virginia and Florida; Recent: North Carolina to the West Indies, Brazil.

Occurrence in this study.—Locality 17c.

Type information.—Holotype: unknown. Figured hypotype: USNM 218210.

Discussion.—A single, mostly exfoliated specimen was found whose outline and preserved features tentatively indicate this species. *S. subovata* (Say, 1824) of the Pliocene is of similar size and shape, but its concentric sculpture is much more strongly developed and it lacks the oblique incised lines of *S. purpurascens*.

Genus **CUMINGIA** Sowerby, 1833

Cumingia tellinoides (Conrad, 1831)
Plate 9, figures 2, 5

Mactra tellinoides Conrad, 1831, p. 258, pl. 9, figs. 2–3.
Cumingia tellinoides (Conrad). Dall, 1900, p. 1000.
Cumingia tellinoides Conrad. [*sic*] Abbott, 1954, p. 436.
Cumingia tellinoides (Conrad). Richards, 1962, p. 67, pl. 10, figs. 29–30.

Diagnosis.—Shell small to moderate in size; thin, strong; ovate-trigonal. Surface with thin, incised, concentric lamellae with much wider interspaces. Hinge with a prominent, oval chondrophore. Shell outline variable within limits.

Measurements.—Length, 22.0 mm; height, 15.5 mm.

Distribution.—Upper Pliocene: North Carolina; Pleistocene: Massachusetts to Florida and Louisiana; Recent: Nova Scotia to Florida.

Occurrence in this study.—Localities 7, 15, 17c, 17d, 18d, 20a, 20b, 22a, 22b, 25a, 26a.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218212.

Discussion.—Species of *Cumingia* are nestlers, a habit producing a wide variety of forms and distortions. The Virginia Pliocene contains a species, *C. medialis* (Conrad, 1866) that duplicates *C. tellinoides* in form and variation but that has more (25 to 30 vs. 18 to 20) concentric lamellae per cm.

Genus **ABRA** Lamarck, 1818

Abra aequalis (Say, 1822)
Plate 9, figures 1, 4

Amphidesma aequalis Say, 1822, p. 307.
Abra aequalis (Say). Dall, 1900, p. 998.
Abra aequalis Say. [*sic*] Abbott, 1954, p. 437, pl. 30, fig. v.
Abra aequalis (Say). Richards, 1962, p. 67, pl. 10, fig. 26.

Diagnosis.—Shell small, oval, inflated, thin. Surface smooth, with weak growth lines. Beaks small, very low.

Measurements.—Length, 10.0 mm; height, 7.8 mm.

Distribution.—Lower Pliocene: Virginia to Florida; Upper Pliocene: North Carolina to Florida; Pleistocene: New York to Florida, Texas, Panama; Recent: Virginia to Texas and the West Indies.

Occurrence in this study.—Localities 15, 17c, 17f, 18b, 18d, 18e, 21a, 26a, 27.

Type information.—Syntypes: ANSP 53231, ANSP 53227. Figured hypotype: USNM 218211.

Family **SOLECURTIDAE** d'Orbigny, 1846

Genus **TAGELUS** Gray, 1847

Tagelus divisus (Spengler, 1794)
Plate 8, figures 15, 17

Solen divisus Spengler, 1794, p. 96.
Tagelus divisus (Spengler). Dall, 1900, p. 985.
Tagelus divisus Spengler. [*sic*] Abbott, 1954, p. 440, pl. 30, fig. g.
Tagelus divisus (Spengler). Richards, 1962, p. 68, pl. 11, fig. 15.

Diagnosis.—Shell of moderate size, elliptical, thin, elongate, smooth. Dorsal and ventral sides parallel, anterior and posterior ends well rounded. Interior with a thickened perpendicular ridge from the central beaks to the base of the shell.

Measurements.—Length, 31.0 mm; height, 10.8 mm.

Distribution.—Lower Pliocene: Florida; Upper Pliocene: Florida; Pleistocene: Virginia to Florida and Louisiana; Recent: Cape Cod to the Caribbean, Brazil.

Occurrence in this study.—Localities 18e, 20b.

Type information.—Holotype: unknown. Figured hypotype: USNM 409329.

Tagelus plebeius (Lightfoot, 1786)
Plate 8, figures 16, 18

Solen plebeius Lightfoot, 1786, p. 42.
Solen gibbus Spengler, 1794, p. 104.
Siliquaria carolinensis Conrad, 1863, p. 585.
Tagelus gibbus (Spengler). Dall, 1900, p. 983.
Tagelus gibbus (Spengler). Gardner, 1943, p. 107, pl. 22, figs. 1–4.
Tagelus plebeius Solander. [*sic*] Abbott, 1954, p. 440, pl. 30, fig. d.
Tagelus gibbus (Spengler). Richards, 1962, p. 68, pl. 11, fig. 16.
Tagelus plebeius (Lightfoot). Rehder, 1967, p. 11.

Diagnosis.—Shell large, elongate, rectangular, thin. Surface smooth save for growth lines. Hinge nearly central with a prominent nympha.

Measurements.—Length, 80.0 mm; height, 28.0 mm.

Distribution.—Lower Pliocene: Virginia to Florida, Mexico?; Upper Pliocene: North Carolina to Florida; Pleistocene: Massachusetts, to South Carolina, Louisiana; Recent: Cape Cod to Florida, Gulf States, and Brazil.

Occurrence in this study.—Localities 9, 17e, 17f, 18e, 20b, 21a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218209.

Discussion.—This species is typically an intertidal species common in mud flats and estuaries. *T. carolinensis* (Conrad, 1863) of the Pliocene is here considered a synonym.

Family **VENERIDAE** Rafinesque, 1815

Genus **MERCENARIA** Schumacher, 1817

Mercenaria campechiensis (Gmelin, 1790)
Plate 7, figures 1–3, 6

Venus campechiensis Gmelin, 1790, p. 3287.
Venus campechiensis Gmelin. Dall, 1903, p. 1315.
Mercenaria campechiensis Gmelin. [*sic*] Abbott, 1954, p. 406, pl. 32, fig. g.
Mercenaria campechiensis (Gmelin). Richards, 1962, p. 65, pl. 9, figs. 12, 14, 16.
Mercenaria campechiensis (Gmelin). Abbott, 1968, p. 230, fig. 3.

Diagnosis.—Shell large, heavy, oval, strong. Surface with thin, concentric lamellae in early growth (Pl. 7, fig. 3) thickening into crowded concentric cords with mature growth. Sculpture is evenly continuous over the entire shell. Hinge large, massive.

Measurements.—Length, 101.0 mm; height, 84.0 mm.

Distribution.—Lower Pliocene: Virginia to Florida; Upper Pliocene: North Carolina to Florida; Pleistocene: New York to Florida and Gulf States; Recent: New Jersey to Florida, Texas, and Yucatan.

Occurrence in this study.—Localities 13, 15, 17b, 17c, 17d, 18a, 18b, 18d, 19a, 20a, 20b, 21a, 22a, 22b, 25a, 26a, 27.

Type information.—Holotype: unknown. Figured hypotypes: USNM 218196, 409332.

Discussion.—The Pliocene of Virginia and North Carolina possesses three large species closely related to *M. campechiensis. M. tridacnoides* (Lamarck, 1818) is a massive, deformed shell whose valves may exceed an inch in thickness: *M. rileyi* (Conrad, 1838) is thin-shelled and may be the "normal" form of *M. tridacnoides.* Both frequently possess an undulating ventral margin. *M. permagna* Conrad, 1838, more closely resembles typical *M. campechiensis* in having a straight ventral margin and in general proportions. *M. permagna* is perhaps a bit heavier and has finer concentric sculpture, but should probably be considered a subspecies.

Mercenaria mercenaria (Linné, 1758)
Plate 6, figures 16, 17

Venus mercenaria Linné, 1758, p. 686.
Venus mercenaria Linné. Dall, 1903, pp. 1311–1312.
Mercenaria mercenaria Linné. [*sic*] Abbott, 1954, p. 406, pl. 32, fig. n.
Mercenaria mercenaria (Linné). Richards, 1962, p. 65, pl. 9, fig. 13.
Mercenaria mercenaria (Linné). Abbott, 1968, p. 230, fig. 1.

Diagnosis.—Shell large, heavy, triangular, strong. Sculpture of thin, low concentric threads that become obsolete over the middle of the disk.

Measurements.—Length, 89.5 mm; height, 75.5 mm.

Distribution.—Miocene: Maryland and Virginia; Lower Pliocene: Virginia to North Carolina, Texas; Upper Pliocene: North Carolina to Florida; Pleistocene: Massachusetts to Georgia and Louisiana; Recent: Gulf of St. Lawrence to Florida, introduced to California.

Occurrence in this study.—Localities 5, 7, 8, 12, 13, 15, 17c, 17e, 20a, 20b, 21a, 27, 28, 30.

Type information.—Holotype: unknown. Figured hypotype: USNM 218195.

Discussion.—The differences between this and *M. campechiensis* (Gmelin, 1790) are well discussed and illustrated by Abbott (1968, p. 230). Adult specimens are distinct, but juvenile specimens are more easily confused.

Genus **PITAR** Römer, 1857

Pitar morrhuana (Linsley, 1845)
Plate 6, figures 10, 13

Cytherea morrhuana Linsley, 1845, p. 276.
Callocardia (*Agripoma*) *morrhuana* (Linsley). Dall, 1903, pp. 1262–1264.
Pitar morrhuana Linsley. [*sic*] Abbott, 1954, p. 414, pl. 32, fig. l; fig. 81e.
Pitar morrhuana (Linsley). Richards, 1962, p. 64, pl. 8, figs. 16–17.

Diagnosis.—Shell of moderate size, oval, thin but strong. Sculpture of fine, very crowded, concentric lines. Beaks well rounded. Hingeline strong with prominent cardinals.

Measurements.—Length, 37.5 mm; height, 37.0 mm.

Distribution.—Lower Pliocene: Virginia to South Carolina; Pleistocene: New York to North Carolina; Recent: Gulf of St. Lawrence to North Carolina.

Occurrence in this study.—Localities 15, 17d, 17e, 18b, 18c, 18d, 18e, 25a, 28.

Type information.—Holotype: unknown. Figured hypotype: USNM 218304.

Discussion.—Much confusion surrounds this species and its predecessor, the Mio-Pliocene (and Recent?) *P. sayana* (Conrad, 1833) because of the multitude of ontogenetic and geographical variants. Resolution of the problem is beyond the scope of this paper.

Genus **MACROCALLISTA** Meek, 1876

Macrocallista nimbosa (Lightfoot, 1786)

Venus nimbosa Lightfoot, 1786, p. 175.
Venus gigantea Gmelin, 1790, p. 3282.
Macrocallista nimbosa (Solander). Dall, 1903, pp. 1254–1255.
Macrocallista nimbosa Solander. [*sic*] Abbott, 1954, p. 416, pl. 39, fig. b.
Macrocallista nimbosa (Solander). Richards, 1962, p. 64, pl. 19, fig. 1.
Macrocallista nimbosa (Lightfoot). Rehder, 1967, p. 29.

Diagnosis.—Shell moderate to large, oval, elongate, thin, rather brittle, very smooth. Beaks low, placed about one-third the distance from the anterior end.

Distribution.—Upper Pliocene: North Carolina to Florida; Pleistocene: Virginia to Florida and Texas; Recent: North Carolina to Florida and Texas.

Occurrence in this study.—Localities 18d, 19a.

Type information.—Neoholotype: MCZ 76665.

Discussion.—All Virginia Pleistocene specimens of this large species are juvenile, suggesting conditions suitable for occasional larval influx, but unsuitable for mature growth. The size classes suggest mortality at the close of the first and second years.

Juveniles of this species and of *M. reposta* (Conrad, 1834) (Lower Pliocene, Virginia to Florida) can be easily confused, but *M. nimbosa* is always more elongate and lighter in the adult form when compared with adult *M. reposta.*

The correct authorship of this species was established by Rehder (1967).

Genus **DOSINIA** Scopoli, 1777

Dosinia discus (Reeve, 1850)
Plate 6, figures 11, 15

Artemis discus Reeve, 1850, pl. 2, fig. 9.
Dosinia discus (Reeve). Dall, 1903, p. 1232.
Dosinia discus Reeve. [*sic*] Abbott, 1954, p. 417, pl. 38, fig. o; fig. 81c.
Dosinia discus (Reeve). Richards, 1962, p. 64, pl. 8, fig. 18.

Diagnosis.—Shell large, circular, very compressed. Concentric sculpture of narrow, flat cords with interspaces of incised lines. Hingeline large, flat, with three strong, thin cardinals on the left valve.

Measurements.—Length, 82.0 mm; height, 75.0 mm.

Distribution.—Upper Pliocene: North Carolina to Florida; Pleistocene: Virginia to Florida and Louisiana; Recent: Virginia to Florida, Yucatan, and the Bahamas.

Occurrence in this study.—Localities 17e, 18e.

Type information.—Holotype: unknown. Figured hypotype: USNM 218194.

Discussion.—This species averages 20 concentric ribs per cm as compared with a mean of 14 per cm for *D. acetabulum* (Conrad, 1832b) of the underlying Pliocene.

Genus **GEMMA** Deshayes, 1853

Gemma purpurea (Lea, 1842)
Plate 6, figures 14, 18

Cyrena purpurea Lea, 1842, p. 106.
Gemma gemma var. *purpurea* (Lea). Dall, 1903, p. 1332.
Gemma gemma purpurea Lea. [*sic*] Abbott, 1954, p. 418, fig. 84c–e.
Gemma gemma (Totten). Richards, 1962, p. 65, pl. 9, figs. 8–11.
Gemma purpurea (Lea). Andrews, 1971, p. 209.

Diagnosis.—Shell very small, triangular, heavy and solid. Sculpture of concentric threads with equal interspaces. Interior ventral margin crenulate.

Measurements.—Length, 3.8 mm; height, 3.6 mm.

Distribution.—Upper Pliocene: North Carolina; Pleistocene: Massachusetts (?) to Alabama; Recent: Cape Cod to Florida, Texas, the Bahamas, and Puerto Rico.

Occurrence in this study.—Localities 17c, 18b, 18d, 20b, 26a.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218193.

Discussion.—Many authors have considered this species to be a variant of *G. gemma* (Totten, 1834), but the two are here considered distinct. *G. gemma* has an oval shell, is slightly smaller, and does not live south of Long Island. *G. purpurea* is the southern species, ranging from Cape Cod to Florida, Texas, and Puerto Rico. No attempt has been made to reexamine the material reported in the literature and consequently, the Pleistocene distribution of the species must be considered tentative.

Family **PETRICOLIDAE** Deshayes, 1830

Genus **PETRICOLA** Lamarck, 1801

Petricola pholadiformis Lamarck, 1818
Plate 7, figures 4, 5

Petricola pholadiformis Lamarck, 1818, p. 505.
Petricola pholadiformis Lamarck. Dall, 1900, p. 1061.
Petricola pholadiformis Lamarck. Gardner, 1943, p. 117.

Petricola pholadiformis Lamarck. Abbott, 1954, p. 420, pl. 32, fig. z; fig. 94b.
Petricola pholadiformis Lamarck. Richards, 1962, p. 65, pl. 10, figs. 1–4.

Diagnosis.—Shell of moderate size, elongate, somewhat inflated, relative proportions variable. Anterior and posterior ends rounded. Sculpture of concentric growth lines beading the dominant radial ribs and riblets; sculpture coarsest over the anterior third of the shell. Hinge with three small cardinals under the right beak. Outline variable.

Measurements.—Length, 44.5 mm; height, 27.0 mm.

Distribution.—Lower Pliocene: Virginia; Upper Pliocene: North Carolina; Pleistocene: Massachusetts to Georgia, Louisiana; Recent: Canada to Uruguay, Europe.

Occurrence in this study.—Localities 17b, 17c, 17e, 18b, 18d, 18e, 19a, 20b, 25a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218197.

Discussion.—This wide-ranging species is particularly common in the top of the worm-rock reefs where it is a nestler. *P.* (*Rupellaria*) *pectrosa* (Conrad, 1834) (= *P.* (*R.*) *grinelli* Olsson, 1914), rare in the Virginia Pliocene, is less regular in its sculpture and more tapered posteriorly.

Family **MYIDAE** Linné, 1758

Genus **MYA** Linné, 1758

Mya arenaria Linné, 1758
Plate 9, figures 3, 6

Mya arenaria Linné, 1758, p. 670.
Mya arenaria Linné. Dall, 1898, pp. 857–858.
Mya arenaria Linné. Gardner, 1943, p. 138, pl. 19, figs. 31–32.
Mya arenaria Linné. Abbott, 1954, p. 455, pl. 32, fig. x.
Mya arenaria Linné. Richards, 1962, p. 70, pl. 12, fig. 13.
Mya arenaria Linné. MacNeil, 1965, pp. 33–35, pl. 5, figs. 2–12; pl. 6, figs. 1–15, 17, 18.

Diagnosis.—Shell moderate to large, thin, oval, gaping posteriorly. Shell may or may not taper posteriorly. Hinge of left valve has a large, horizontal chondrophore.

Measurements.—Length, 85.0 mm; height, 57.0 mm.

Distribution.—Miocene: North Pacific; Lower Pliocene: North Pacific, Massachusetts and Virginia; Upper Pliocene: North Pacific, North Carolina; Pleistocene: North Pacific, Hudson Bay to South Carolina, Great Britain to the Netherlands; Recent: North Pacific to California and Japan?, Labrador to North Carolina, Scandinavian coast to France?.

Occurrence in this study.—Localities 17f, 18b, 18d, 18e, 20b, 22b, 22c.

Type information.—Holotype: unknown. Figured hypotype: USNM 218214.

Genus **PARAMYA** Conrad, 1860

Paramya subovata (Conrad, 1845)
Plate 9, figures 13, 18

Myalina subovata Conrad, 1845, p. 65, pl. 36, fig. 4.
Paramya subovata (Conrad). Dall, 1898, pp. 861–862.
Paramya subovata (Conrad). Morris, 1951, p. 90, pl. 18, fig. 4.
Hiatella arctica (Linné). Richards, 1966, p. 24, pl. 3, figs. 6–7, not of Linné, 1767.

Diagnosis.—Shell small, thin, inflated, truncated posteriorly; hinge as in *Corbula*; sculptured with rough concentric growth lines; outline somewhat squarish.

Measurements.—Length, 13.0 mm; height, 9.0 mm.

Distribution.—Miocene: Maryland; Lower Pliocene: Virginia and North Carolina; Upper Pliocene: South Carolina; Pleistocene: Virginia to South Carolina; Recent: Delaware and Texas.

Occurrence in this study.—Localities 17c, 17f, 18d, 18e, 26a.

Type information.—Holotype: $ANSP_p$ (missing). Figured hypotype: USNM 218217.

Discussion.—This species has been reported to be commensal with *Thalassema hartmani* Fisher, 1947, an echiuroid worm (Jenner and McCrary, 1969).

Family **CORBULIDAE** Lamarck, 1818

Genus **CORBULA** Bruguière, 1792

Corbula contracta Say, 1822
Plate 9, figures 11, 12

Corbula contracta Say, 1822, p. 312.
Corbula contracta Say. Dall, 1898, pp. 855–856.
Corbula contracta Say. Abbott, 1954, p. 457.
Corbula contracta Say. Richards, 1962, p. 68, pl. 11, figs. 5, 11, 14.

Diagnosis.—Shell small, elongate, subrectangular, solid. Sculpture of a posterior radial ridge and low, narrow, concentric threads with equal interspaces. Ventral margin straight.

Measurements.—Length, 10.2 mm; height, 6.5 mm.

Distribution.—Upper Pliocene: North Carolina to Florida; Pleistocene: Massachusetts to South Carolina, Louisiana, and Texas; Recent: Cape Cod to Florida and the West Indies, Brazil.

Occurrence in this study.—Localities 17b, 17c, 17d, 17e, 17f, 18a, 18b, 18d, 18e, 19a, 20a, 20b, 21a, 22a, 22b, 26a, 28.

Type information.—Holotype: ANSP 50903. Figured hypotype: USNM 218215.

Corbula swiftiana Adams, 1852
Plate 9, figures 9, 10

Corbula swiftiana Adams, 1852, p. 236.
Corbula (*Cuneocorbula*) *swiftiana* (Adams). Dall, 1898, p. 855.
Corbula swiftiana Adams. Abbott, 1954, p. 458, fig. 93b.

Diagnosis.—Shell small, triangular, very thick, inflated. Sculpture of a posterior radial ridge and low, broad, concentric undulations. Hinge with a single very large cardinal on the right valve. Ventral margin convex.

Measurements.—Length, 7.0 mm; height, 4.8 mm.

Distribution.—Lower Pliocene: South Carolina to Florida; Pleistocene: New York, Virginia and Florida, Panama; Recent: Massachusetts to Venezuela.

Occurrence in this study.—Localities 17f, 18e.

Type information.—Lectotype: MCZ 186103. Paratype: MCZ 155602. Figured hypotype: USNM 218216.

Family **PHOLADIDAE** Lamarck, 1809

Genus **BARNEA** Risso, 1826

Barnea truncata (Say, 1822)
Plate 9, figures 14–17

Pholas truncata Say, 1822, p. 321.
Barnea truncata (Say). Dall, 1898, p. 816.
Barnea truncata Say. [*sic*] Abbott, 1954, p. 461.
Barnea (*Anchosasa*) *truncata* (Say). Turner, 1954, p. 27, pls. 8, 11, 13.
Barnea truncata (Say). Richards, 1962, p. 71, pl. 13, fig. 14.

Diagnosis.—Shell of moderate size, thin, subrectangular, inflated, gaping anteriorly and posteriorly. Sculpture of strong concentric ribs and of radial threads becoming obsolete on the posterior third of the shell. Concentric ribs visible on interior of shell; ribs becoming fimbriate near anteroventral margin. Beaks covered with shelly protoplax. Hinge with a very narrow, elongate, curved projection.

Distribution.—Pleistocene: New Jersey to South Carolina; Recent: Maine to Brazil, Senegal to the Gold Coast.

Occurrence in this study.—Localities 17b, 17c, 17d.

Type information.—Cotype: ANSP 50775. Figured hypotypes: USNM 218218, 218219.

Discussion.—A small bed of this species in the Kempsville sands (loc. 17c) yielded a number of superb specimens complete with protoplax. *Pholas memmingeri* Tuomey and Holmes, 1856, very rare in the Pliocene of Virginia, South Carolina, and Florida, is similar in form but has a septate umbonal reflection that immediately distinguishes it.

Genus **CYRTOPLEURA** Tryon, 1862

Cyrtopleura costata (Linné, 1758)
Plate 9, figures 19, 20

Pholas costatus Linné, 1758, p. 669.
Barnea (*Scobina*) *costata* (Linné). Dall, 1898, p. 816.
Barnea costata Linné. [*sic*] Abbott, 1954, p. 460, fig. 94a.
Cyrtopleura (*Scobinopholas*) *costata* (Linné). Turner, 1954, p. 35, pls. 17–18.

Diagnosis.—Shell large, thin, oval-elongate, inflated, gaping anteriorly and posteriorly. Radial sculpture dominant, of beaded ribs that are stronger and more widely spaced near the anterior and posterior ends. Hinge with a short, broad, spoon-shaped projection.

Measurements.—Length, 104.0 mm; height, 39.5 mm.

Distribution.—Upper Pliocene: Florida; Pleistocene: Massachusetts to Florida and Louisiana; Recent: Massachusetts to Brazil.

Occurrence in this study.—Localities 1, 11, 17e, 18e, 20b, 27.

Type information.—Holotype: unknown. Figured hypotype: USNM 218220.

Discussion.—*C. costata* is abundant in the brackish water faunas exposed at the lowermost level of the Kempsville area pits. Pairs in living position are common but extracting an intact specimen from the matrix is difficult. A related species, *C. arcuata* (Conrad, 1841) from the underlying Pliocene is more elongate and has more numerous ribs, which are more strongly beaded.

Genus **MARTESIA** Sowerby, 1824

Martesia cuneiformis (Say, 1822)
Plate 10, figures 1, 5

Pholas cuneiformis Say, 1822, p. 322.
Martesia cuneiformis Say. [*sic*] Abbott, 1954, p. 465.
Martesia cuneiformis (Say). Turner, 1955, pp. 114–117, pls. 67, 68.
Martesia cuneiformis (Say). Richards, 1962, p. 72, pl. 13, figs. 12–13.

Diagnosis.—Shell small, oval, very thin. Concentric sculpture divided by a deep radial groove. Concentric sculpture anterior of groove crowded, well defined; posterior sculpture lower, undulatory, becoming obsolete. Hinge, when complete, with a very narrow, elongate projection.

Measurements.—Length, 9.4 mm; height, 9.1 mm.

Distribution.—Pliocene: Virginia?; Pleistocene: Maryland to South Carolina; Recent: Breeding—North Carolina to Brazil; adventitious to Connecticut.

Occurrence in this study.—Locality 18b.

Type information.—Holotype: ANSP 50803. Figured hypotype: USNM 409330.

Discussion.—Dall (1898, p. 820) referred the Yorktown Pliocene form of *Martesia* to this species, but the specimens examined do not appear conspecific.

Family **LYONSIIDAE** Fischer, 1887

Genus **LYONSIA** Turton, 1822

Lyonsia hyalina (Conrad, 1831)
Plate 10, figures 9, 10

Mya hyalina Conrad, 1831, p. 261, pl. 11, fig. 12.
Lyonsia hyalina Conrad. [*sic*] Abbott, 1954, p. 468, pl. 28, fig. u.
Lyonsia hyalina (Conrad). Richards, 1962, p. 58, pl. 5, fig. 15.

Diagnosis.—Shell small, subrectangular, very thin, glassy. Sculpture of growth lines and a weakly defined posterior radial rib.

Measurements.—Length, 11.0 mm; height, 6.8 mm.

Distribution.—Pleistocene: Maryland and Virginia; Recent: East Canada to South Carolina.

Occurrence in this study.—Locality 17c.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218223.

Family **PANDORIDAE** Rafinesque, 1815

Genus **PANDORA** Bruguière, 1797

Pandora gouldiana Dall, 1886
Plate 10, figures 2, 6

Pandora trilineata Say. Conrad, 1831, p. 49, pl. x, figs. 1–2 (not of Say, 1822).
Pandora gouldiana Dall, 1886, p. 312.
Pandora (*Clidiophora*) *gouldiana* Dall, 1903, p. 1521.
Pandora gouldiana Dall. Abbott, 1954, p. 470, fig. 96c.
Pandora gouldiana Dall. Richards, 1962, p. 58, pl. 5, fig. 18, pl. 6, figs. 3–4.
Pandora gouldiana Dall. Boss and Merrill, 1965, pp. 190–195, pl. 120.

Diagnosis.—Shell of moderate size, flat, crescent-shaped, relatively broad, nacreous within. Hinge with three large, narrow cardinal teeth.

Measurements.—Length, 22.5 mm; height, 15.0 mm.

Distribution.—Pleistocene: Massachusetts to Virginia; Recent: Gulf of St. Lawrence to North Carolina.

Occurrence in this study.—Localities 17b, 17c, 17d, 18b, 18d, 21a, 22a, 26a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218221.

Discussion.—*P. gouldiana* differs from the Pliocene *P. crassidens* Conrad, 1838, in having the two ribs of the dorsal margin more strongly developed and the anteriormost "tooth" of the hinge ventrally rather than obliquely directed.

Pandora trilineata Say, 1822
Plate 10, figures 3, 7

Pandora trilineata Say, 1822, p. 261.
Pandora (*Clidiophora*) *trilineata* Say. Dall, 1903, p. 1519.
Pandora (*Clidiophora*) *trilineata* Say. Gardner, 1943, p. 49, pl. 11, fig. 7.
Pandora trilineata Say. Abbott, 1954, p. 469, fig. 96b.
Pandora trilineata Say. Richards, 1962, p. 58, pl. 6, fig. 5.

Diagnosis.—Shell small to moderate in size, flat, crescent-shaped, relatively elongate, nacreous within. Dorsal ridge with three cords, shell becoming rostrate posteriorly.

Measurements.—Length, 19.5 mm; height, 11.0 mm.

Distribution.—Lower Pliocene: North Carolina; Pleistocene: New Jersey to Florida and Louisiana; Recent: Virginia to Texas.

Occurrence in this study.—Localities 15, 17c, 17d, 18b, 18d, 19a, 21a, 22b, 26a.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218222.

Discussion.—*P. trilineata* differs from *P. gouldiana* in being much smaller and more elongate. *P. tuomeyi* Gardner and Aldrich, 1919, of the underlying Pliocene has much the same outline but differs from *P. trilineata* in having the two ribs of the hinge margin poorly developed, and in having the anteriormost "tooth" obliquely rather than ventrally directed.

Family **PERIPLOMATIDAE** Dall, 1895

Genus **PERIPLOMA** Schumacher, 1817

Periploma leana (Conrad, 1831)
Plate 10, figures 11, 14

Anatina leana Conrad, 1831, p. 263, pl. XI, fig. 11.
Cochlodesma leanum "Couthouy". Sumner, Osburn, and Cole, 1913, p. 699.
Periploma leana Conrad. [*sic*] Abbott, 1954, p. 474, pl. 28, fig. v.

Diagnosis.—Shell of moderate size, very compressed, elliptical, smooth, very thin. Hinge with a small, vertical, spoon-shaped chondrophore supported by a thickened, posteriorly-directed internal ridge.

Measurements.—Length, 23.4 mm; height, 16.0 mm.

Distribution.—Pleistocene: Virginia and South Carolina; Recent: Gulf of St. Lawrence to North Carolina.

Occurrence in this study.—Localities 17c, 18b, 18d, 19a, 21a, 22a, 26a.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218224.

Discussion.—*P. antiqua* (Conrad, 1834), a slightly larger, heavier species very rare in the lower Pliocene of Virginia and Florida, is very close to this species and is probably precursor to it. In *P. leana,* the pallial sinus is more V- than U-shaped and the chondrophore is more ventrally directed.

Class **GASTROPODA** Dumeril 1806

Family **SKENEIDAE** Thiele, 1929

Genus **SKENEA** Fleming, 1825

Skenea species
Plate 10, figures 12, 16, 19

Diagnosis.—Shell minute, 0.5–0.7 mm in diameter, naticoid, two-and-a-half to three whorls, umbilicus deep, narrow, no umbilical chink developed. Umbilical keel strong with 16 to 20 narrow ridges radiating from it over the base of the shell; spiral incised lines in the umbilical wall; upper surface smooth except for faint growth lines. Aperture, oval, with a distinct opercular shelf.

Measurements.—Length, 0.4 mm; body whorl diameter, 0.9 mm.

Distribution.—Pleistocene: Virginia; Recent: widespread East Coast, U.S.A.

Occurrence in this study.—Localities 20a, 20b.

Type information.—Figured hypotype, USNM 218226.

Discussion.—Moore (oral comm., 1979) reports this form to be quite common and widespread in the Recent Western Atlantic. Because of the imperfect preservation of our fossil material, the authors thought best to leave the form undescribed. In Virginia Pleistocene sediments that were not sieved too coarsely, this species is common to abundant. Consequently, its absence from most localities is probably a sampling bias.

Family **LITTORINIDAE** Gray, 1840

Genus **LITTORINA** Férussac, 1822

Littorina irrorata (Say, 1822)
Plate 10, figures 4, 8

Turbo irroratus Say, 1822, p. 239.
Littorina irrorata (Say). Dall, 1892, p. 320.
Littorina irrorata (Say). Bequaret, 1943, p. 6, pl. 2, figs. 1–7.
Littorina irrorata Say. [*sic*] Abbott, 1954, p. 132, pl. 19, fig. c.
Littorina irrorata (Say). Richards, 1962, p. 77, pl. 15, fig. 32.

Diagnosis.—Shell of moderate size, trochoid, very thick and solid. Spire evenly tapering. Sculpture of about 20 spiral cords; cords strongest just below the suture, becoming very narrow on the base. Aperture oval.

Measurements.—Length, 20.0 mm; body whorl diameter, 15.0 mm.

Distribution.—Miocene (?): Maryland; Pliocene: Virginia? to South Carolina; Plio-Pleistocene: North Carolina to Florida; Pleistocene: Connecticut to Georgia, Louisiana; Recent: Massachusetts (?), New York to central Florida and Texas.

Occurrence in this study.—Localities 8, 11, 17f.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218227.

Family **RISSOIDAE** Gray, 1840

Genus **CINGULA** Fleming, 1828

Cingula norfolkensis, new species
Plate 10, figure 13

Etymology.—Named for the Norfolk area.

Description.—Shell very small, slender, elongate, fragile; whorls five, gently and evenly rounded; protoconch large. Suture distinctly impressed. Umbilical slit long and very narrow. Sculpture of about 40 spiral, incised lines on the body whorl. Aperture oblique, oval; outer lip broken, apparently flaring when whole.

Measurements.—Length, 2.2 mm; body whorl diameter, 1.2 mm.

Distribution.—Pleistocene: Virginia.

Occurrence in this study.—Localities 17c, 20b.

Discussion.—This species is narrower than the three living Western Atlantic species figured by Abbott (1974, p. 74), but Abbott makes no mention of *Rissoa cretacea* Stimpson, 1854, *R. modesta* Stimpson, 1854, *R. mortoni* Kurtz, 1860, and *R. patens* Gould, 1862 as cited in Mazyck (1913), nor of *Cingula turriculus* (Lea, 1843). There is a critical need for a monograph of the Western Atlantic rissoids, an effort begun by the late Dr. J. P. E. Morrison, but never completed. Morrison (oral commun., 1972) examined the Virginia fossil and pronounced it unique, but most closely related to an undescribed Recent species from Maryland.

Type information.—Holotype: USNM 409331.

Family **HYDROBIIDAE** Stimpson, 1865

Genus **HYDROBIA** Hartmann, 1821

Hydrobia totteni Morrison, 1954
Plate 10, figure 15

Turbo minutus Totten, 1835, p. 369, figs. 6a, b (not *T. minutus* of Brown, 1816, Michaud, 1828, or Woodward, 1833).
Hydrobia totteni Morrison, 1954, p. 26.

Diagnosis.—Shell small, thin, high-spired. Whorls five-and-one-half, very round and inflated. Surface smooth. Aperture circular, entire. Umbilicus narrow, very deep.

Measurements.—Length, 3.2 mm; body whorl diameter, 1.8 mm.

Distribution.—Pleistocene: Virginia; Recent: Labrador to North Carolina.

Occurrence in this study.—Localities 17c, 26a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218228.

Family **VITRINELLIDAE** Bush, 1897

Genus **VITRINELLA** Adams, 1850

Vitrinella floridana Pilsbry and McGinty, 1946b
Plate 10, figures 17, 18

Vitrinella floridana Pilsbry and McGinty, 1946b, p. 16.
Vitrinella floridana Pilsbry and McGinty. Andrews, 1971, pp. 72–73.

Diagnosis.—Shell minute, smooth, planorbid, thin. Whorls three, rapidly expanding. Aperture entire, circular. Umbilicus wide, deep, funnel-shaped.

Measurements.—Length, 0.5 mm; body whorl diameter, 1.1 mm.

Distribution.—Pleistocene: Virginia, Texas?; Recent: North Carolina and Texas to Campeche, Mexico.

Occurrence in this study.—Localities 20a, 20b.

Type information.—Holotype: ANSP 181880. Figured hypotype: USNM 218229.

Discussion.—The species is rare in the Virginia Pleistocene. Juveniles can be separated from *Skenea* sp. by their wide umbilicus and lack of sculpture.

Genus CIRCULUS Jeffreys, 1865

Circulus liratus (Verrill, 1882)
Plate 11, figures 1, 4

Omalaxis (?) *lirata* Verrill, 1882, p. 529.
Cyclostremiscus liratus (Verrill). Pilsbry, 1953, p. 430.
"*Circulus*" (?*supra-nitidus* Wood subsp.) *orbignyi* (Fischer). Gardner, 1948, p. 189, pl. 25, fig. 33 (not of Fischer, 1857, p. 286).
Cyclostremiscus pentagonus (Gabb). Abbott, 1974, p. 84, fig. 785 (not of Gabb, 1873).

Diagnosis.—Shell minute, planorbid, thin. Whorls four, rapidly expanding. Sculpture of strong spiral threads on the dorsal surface, periphery, and bordering the umbilicus. Base smooth. Umbilicus deep.

Measurements.—Length, 1.0 mm; body whorl diameter, 2.1 mm.

Distribution.—Upper Pliocene: North Carolina to Florida; Pleistocene: Virginia; Recent: Long Island to Florida.

Occurrence in this study.—Localities 17c, 18b, 18d, 19a, 26a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218231.

Discussion.—This species is the most common of our larger Pleistocene vitrinellids, but is apparently rare in Recent collections. *C. costulatus* (Lea, 1843) from the Yorktown Pliocene is a similar, probable ancestral species. This species is little known, but can not be confused with *Cyclostremiscus pentagonus* (Gabb, 1873), a species which has wide, smooth interspaces between three strong, raised keels.

Genus CYCLOSTREMISCUS Pilsbry and Olsson, 1945

Cyclostremiscus jeannae Pilsbry and McGinty, 1946a
Plate 11, figures 2, 5

Cyclostremiscus (*Ponocyclus*) *jeannae* Pilsbry and McGinty, 1946a, p. 82, pl. 8, figs. 4, 4a.
Cyclostremiscus (*Ponocyclus*) *jeannae* Pilsbry and McGinty. Andrews, 1971, pp. 66–67 (fig. d).

Diagnosis.—Shell minute, planorbid, thin. Whorls four, rapidly expanding. Sculpture lacking except for two strong spiral keels at the upper and lower margins of the periphery. Aperture squarish. Umbilicus wide, very deep.

Measurements.—Length, 1.3 mm; body whorl diameter, 2.3 mm.

Distribution.—Pleistocene: Virginia; Recent: Both sides of Florida to Texas.

Occurrence in this study.—Locality 20b.

Type information.—Holotype: ANSP 181371. Figured hypotype: USNM 218232.

Genus SOLARIORBIS Conrad, 1865

Solariorbis infracarinata (Gabb, 1881)
Plate 11, figures 3, 6, 7

Adeorbis infracarinata Gabb, 1881, p. 365, pl. 46, fig. 62.
Solariorbis euzonus Pilsbry and McGinty, 1950, p. 84, pl. 5, figs. 7, 7a.
Solariorbis infracarinata (Gabb). Andrews, 1971, pp. 70–71.

Diagnosis.—Shell minute, planorbid, biconvex. Whorls three-and-one-half, rapidly expanding, overlapping. Sculpture of spiral lines restricted to periphery and outer edge of base; lines coarsening on the base. Umbilicus very narrow, deep, roofed over.

Measurements.—Length, 0.8 mm; body whorl diameter, 1.7 mm.

Distribution.—Pleistocene: Virginia to Florida; Recent: Virginia to Florida, Texas, Mexico to Guatemala.

Occurrence in this study.—Locality 20b.

Type information.—Holotype: $ANSP_p$ 3380. Figured hypotype: USNM 218233.

Solariorbis cf. **S. blakei** Rehder, 1944
Plate 11, figures 8, 9, 17

Solariorbis blakei Rehder, 1944, p. 97.
Solariorbis blakei Rehder. Abbott, 1974, p. 88.

Diagnosis.—Shell minute, 0.7 to 0.9 mm in length, twice as broad as high, whorls rounded with no keel developed; spirals extremely faint over upper surface, becoming more incised and visible towards the periphery, then continuing evenly to the base where they again become faint while crossing the basal axial sculpture; basal axial cords originate deep within the umbilicus and are closely crowded as they emerge, giving the umbilicus a "pinched" appearance.

Measurements.—Length, 0.5 mm; body whorl diameter, 1.1 mm.

Distribution.—Pleistocene: Virginia; Recent: South Carolina to Texas and Caribbean.

Occurrence in this study.—Localities 17c, 20b.

Type information.—Hypotype: USNM 218234.

Discussion.—This species may prove to be *Solariorbis shimeri* (Clapp, 1914), a species very imperfectly known.

Genus TEINOSTOMA Adams and Adams, 1854

Teinostoma cryptospira (Verrill, 1884)
Plate 10, figures 20, 21

Rotella cryptospira Verrill, 1884, p. 241.
Teinostoma cryptospira (Verrill). Dall, 1892, p. 414.
Teinostoma cryptospira Verrill. [*sic*] Abbott, 1954, pl. 17, fig. y.
Teinostoma cryptospira (Verrill). Richards, 1962, p. 73, pl. 14, figs. 15–17.

Diagnosis.—Shell minute, planorbid, smooth and polished. Whorls three, totally overlapping on the spire. Umbilicus completely filled by callus. Aperture circular.

Measurements.—Length, 0.4 mm; body whorl diameter, 1.5 mm.

Distribution.—Pleistocene: Maryland to Florida; Recent: Virginia to both sides of Florida.

Occurrence in this study.—Localities 17b, 17c, 17d, 20b.

Type information.—Holotype: unknown. Figured hypotype: USNM 218230.

Discussion.—This minute species is common in fine-screened samples. The upper surface is completely covered by a thin callus that breaks away easily in the fossils to reveal the underlying spiral suture.

Family **CAECIDAE** Gray, 1850

Genus **CAECUM** Fleming, 1813

Caecum cooperi Smith, 1860
Plate 11, figure 10

Caecum cooperi Smith, 1860, pp. 154, 168.
Caecum cooperi Smith. Dall, 1892, p. 299.
Caecum cooperi Smith. Richards, 1962, p. 78.
Caecum cooperi Smith. Abbott, 1974, p. 92, fig. 877.

Diagnosis.—Shell minute, cylindrical, tusk-shaped. Protoconch coiled, planorbid; typically broken away from adult shells. Postnuclear growth not coiled. Sculpture of 18 to 20 longitudinal ribs and two or three strong annulations at the aperture. Aperture circular. Apex plug with a projecting mucro.

Measurements.—Length, 3.6 mm; maximum diameter, 0.8 mm.

Distribution.—Lower Pliocene: Virginia to Florida; Upper Pliocene: North Carolina to Florida; Pleistocene: Virginia to South Carolina; Recent: Cape Cod to Florida and Texas.

Occurrence in this study.—Localities 17b, 18a, 20b, 26a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218235.

Caecum johnsoni Winkley, 1908
Plate 11, figures 11–13

?*Dentalium glabrum* Montagu, 1803, p. 497.
?*Caecum glabrum* (Montagu). Meyer, 1888, p. 140.
Caecum johnsoni Winkley, 1908, p. 54.
?*Caecum putnamense* Mansfield, 1924, pp. 46–47, pl. 1, figs. 1, 2.
Caecum glabrum (Montagu). Andrews, 1971, pp. 75–76.

Diagnosis.—Shell minute, reaching 2.5 mm; curved, tusk-like; plug mammalate (dome-shaped); sculpture smooth except for very fine lines of growth.

Measurements.—Length, 2.0 mm; maximum diameter, 0.47 mm.

Distribution.—Lower Pliocene: Virginia, Florida?, Great Britain; Pleistocene: Virginia; Recent: Massachusetts to Texas, Great Britain.

Occurrence in this study.—Localities 19a, 20b.

Type information.—Holotype: MCZ (lost). Figured hypotypes: USNM 218236, 218237, 218238.

Discussion.—*C. glabrum* is the oldest of the above names. All have smooth, glistening sculptureless shells with mammalate plugs and essentially the same curvature. Size is highly variable in populations of *Caecum*, but all of the above have essentially the same maximum (~2.5 mm). We have used the name *C. johnsoni* because its type is from the Western Atlantic; if more than one species does exist, that determination will have to be based on soft parts, or demonstration of interbreeding incapability. *C. occidentale* Bartsch, 1920, of the Pacific coast, differs in reaching a greater maximum size.

Family **CERITHIIDAE** Fleming, 1822

Genus **DIASTOMA** Deshayes, 1850

Diastoma alternatum (Say, 1822)

Bittium alternatum Say, 1822, p. 243.
Bittium alternatum Say. Abbott, 1954, p. 155.
Bittium alternatum Say. Richards, 1962, p. 78, pl. 17, fig. 6.
Diastoma alternatum (Say). Abbott, 1974, p. 187, fig. 1035.

Diagnosis.—Shell very small, high-spired, thin. Sculpture of eight to 10 spiral cords; axial sculpture, when present, of about 16 low riblets. Aperture obliquely oval, with a very shallow siphonal notch at the base.

Distribution.—Pleistocene: Virginia; Recent: Gulf of St. Lawrence to Virginia.

Occurrence in this study.—Localities 13, 17d.

Type information.—Holotype: ANSP (missing).

Genus **CERITHIOPSIS** Forbes and Hanley, 1848

Cerithiopsis emersoni (Adams, 1839)
Plate 11, figure 16

?*Murex subulatus* Montagu, 1808, p. 115, pl. 30, fig. 6.
Cerithium emersoni Adams, 1839, p. 284, pl. 4, fig. 10.
Cerithiopsis subulata (Montagu). Dall, 1892, p. 268.
Cerithiopsis emersoni persubulata Gardner, 1948, p. 204, pl. 27, fig. 4.
Cerithiopsis emersoni (Adams). Olsson and Harbison, 1953, p. 301.
Cerithiopsis subulata Montagu. [*sic*] Abbott, 1954, p. 157, pl. 19, fig. w.
Cerithiopsis emersoni (Adams). Warmke and Abbott, 1961, pp. 74–75, pl. 13, fig. c.
Cerithiopsis subulata (Montagu). Richards, 1962, p. 78, pl. 17, figs. 4–5.
Cerithiopsis emersoni (Adams). Abbott, 1974, p. 109, fig. 1051.

Diagnosis.—Shell small, high-spired, solid, straight-sided. Sculpture of beaded spirals; no spirals on base.

Measurements.—Length, 2.1 mm; body whorl diameter, 0.92 mm.

Distribution.—Lower Pliocene: Virginia to Florida, Trinidad; Upper Pliocene: North Carolina to Florida and Venezuela; Pleistocene: New Jersey to Florida; Recent: Massachusetts to the West Indies, Brazil.

Occurrence in this study.—Locality 20b.

Type information.—Lectotype; MCZ 156201. Figured hypotype: USNM 218239.

Cerithiopsis greeni (Adams, 1839)
Plate 11, figure 26

Cerithium greeni Adams, 1839, p. 287, pl. 4, fig. 12.
Cerithiopsis greeni (Adams). Dall, 1892, p. 269.
Cerithiopsis greeni Adams. [*sic*] Abbott, 1954, p. 157, pl. 19, fig. v.
Cerithiopsis greeni (Adams). Richards, 1962, p. 78, pl. 17, fig. 2.

Diagnosis.—Shell very small, high-spired, solid, bullet-shaped. Sculpture of heavily-beaded spirals; base spirals smooth. Aperture circular, with a deep siphonal notch.

Distribution.—Upper Pliocene: Florida; Pleistocene: Massachusetts to Florida; Recent: Cape Cod to Florida and Texas, West Indies, Brazil.

Occurrence in this study.—Localities 17c, 17d, 17e, 17f, 20b, 26a.

Type information.—Lectotype: MCZ 156202. Figured hypotype; USNM 218240.

Discussion.—*C. smithfieldensis* Olsson, 1916, of the Pliocene averages smaller than *C. greeni* and is more slender, but their sculpture is very similar.

Genus **SEILA** Adams, 1861

Seila adamsii (Lea, 1845)
Plate 11, figures 14, 15

Cerithium terebrale Adams, 1840, p. 320, pl. 3, fig. 7 (not *C. terebrale* Lamarck, 1804).
Cerithium clavulus Lea, 1843, p. 11 (not *C. clavulus* Deslongchamps, 1842).
Cerithium clavulus Lea, 1845, p. 42, pl. 37, fig. 89.
Cerithium adamsii Lea, 1845, p. 42 (bottom of page).
Cerithium annulatum Emmons, 1858, p. 269, fig. 161.
Seila adamsii (Lea). Dall, 1892, p. 267.
Seila adamsii Lea. [*sic*] Abbott, 1954, p. 158, pl. 22, fig. t.
Seila adamsii (Lea). Richards, 1962, p. 78, pl. 17, fig. 3.

Diagnosis.—Shell small, high-spired, straight-sided, solid. Sculpture of three strong, unbeaded spiral cords with deep interspaces; microscopic axial lines visible in interspaces only.

Measurements.—Length, 3.9 mm; body whorl diameter, 1.6 mm.

Distribution.—Miocene: Maryland to Florida; Lower Pliocene: Virginia to Florida, Trinidad; Upper Pliocene: North Carolina to Florida, Venezuela; Pleistocene: Massachusetts to Florida, Texas, and Brazil.

Occurrence in this study.—Localities 7, 17c, 17d, 17f, 26a.

Type information.—Lectotype: MCZ 156200. Figured hypotype: USNM 218241.

Genus **TRIPHORA** Blainville, 1828

Triphora nigrocincta (Adams, 1839)
Plate 11, figures 18, 19

Cerithium nigrocincta Adams, 1839, p. 286, pl. 4.
Triphora nigrocincta Adams. [*sic*] Abbott, 1954, p. 159.
Triphora nigrocincta (Adams). Richards, 1962, p. 78, pl. 17, fig. 6.

Diagnosis.—Shell very small, sinistral, high-spired, solid. Whorls eight; sides of spire convex. Sculpture of three coarsely-beaded spiral cords per whorl.

Measurements.—Length, 4.6 mm; body whorl diameter, 1.8 mm.

Distribution.—Upper Pliocene: North Carolina to Florida; Pleistocene: New Jersey to Virginia, Florida; Recent: Massachusetts to the West Indies, Brazil.

Occurrence in this study.—Localities 17d, 17e, 17f, 25a, 26a.

Type information.—Lectotype: MCZ 186159. Figured hypotype: USNM 218242.

Family **EPITONIIDAE** Berry, 1910

Genus **EPITONIUM** Röding, 1798

Epitonium angulatum (Say, 1830)
Plate 11, figures 20, 21

Scala clathrus angulata Say, 1830, pl. 27.
Epitonium angulatum Say. [*sic*] Abbott, 1954, p. 164, pl. 22, fig. b.
Epitonium angulatum (Say). Richards, 1962, p. 74, pl. 14, fig. 28.

Diagnosis.—Shell small, high-spired, thin. Whorls strongly convex, inflated; suture very deep. Spiral sculpture and basal cord lacking. Axial sculpture of nine to 10 thin, bladelike costae per whorl.

Measurements.—Length, 10.5 mm; body whorl diameter, 5.9 mm.

Distribution.—Upper Pliocene: North and South Carolina; Pleistocene: Maryland to South Carolina and Louisiana; Recent: New York to Florida to Texas.

Occurrence in this study.—Localities 17c, 17d, 17f, 18b, 18d, 18e, 26a.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218243.

Epitonium championi Clench and Turner, 1952
Plate 11, figures 22, 23

Epitonium (*Asperiscala*) *championi* Clench and Turner, 1952, p. 318, pl. 153.
Epitonium candeanum (d'Orbigny). Richards and Campbell, 1972, p. 10, fig. 17.

Diagnosis.—

Shell reaching about 14 mm (0.5 in.) in length, attenuated, imperforate, rather solid and strongly sculptured. Whorls 10 to 11, convex and attached. Color a flat white to a light cream. Aperture subcircular with both the palatal and parietal margins thickened, the palatal or outer lip being greatly thickened in older specimens. Columella short and arched. Spire extended and produced at an angle of 20°. Suture moderately impressed. Axial sculpture consisting of 8 or 9 flattened ridges, those nearest the umbilical area being a little narrower. Basal ridge absent. Operculum thin, paucispiral, and brown in color. Nuclear whorls 2½ to 3, smooth, and opaque. (Clench and Turner, 1952, p. 231.)

Measurements.—Length, 11.9 mm; body whorl diameter, 5.3 mm.

Distribution.—Pliocene: ? (closely related forms are found Virginia to Florida); Pleistocene: Virginia; Recent: Cape Cod to South Carolina.

Occurrence in this study.—Locality 17c.

Type information.—Holotype: MCZ 182900. Figured hypotype: ANSP 64322.

Epitonium humphreysii (Kiener, 1845)
Plate 11, figures 24, 25

Scalaria humphreysii Kiener, 1845, p. 15, pl. 5, fig. 16.
Epitonium humphreysii (Kiener). Clench and Turner, 1952, p. 268, pl. 117, fig. 2; pls. 119–120.
Epitonium humphreysii Kiener. [*sic*] Abbott, 1954, p. 164, pl. 22, fig. d.
Epitonium humphreysii (Kiener). Richards, 1962, p. 74, pl. 14, figs. 23–24.

Diagnosis.—Shell small, high-spired, slender, thin but strong. Whorls moderately convex. Basal cord and spiral sculpture lacking. Axial sculpture of eight to nine thick, moderately-elevated costae per whorl.

Measurements.—Length, 6.3 mm; body whorl diameter, 3.9 mm.

Distribution.—Pleistocene: New Jersey to South Carolina; Recent: Massachusetts to Florida and Texas.

Occurrence in this study.—Localities 17c, 17d, 19a, 29.

Type information.—Holotype: unknown. Figured hypotype: USNM 218245.

Epitonium multistriatum (Say, 1826)
Plate 12, figures 1, 2

Scalaria multistriata Say, 1826, p. 208.
Epitonium multistriatum (Say). Clench and Turner, 1951, p. 292, pls. 133–134.
Epitonium multistriatum (Say). Richards, 1962, p. 74, pl. 14, fig. 25.
Epitonium multistriatum (Say). Abbott, 1968, p. 96, fig. 11.

Diagnosis.—Shell small, high-spired, very thin. Umbilicus lacking. Sculpture of numerous low, very thin axial costae. Interspaces with crowded, exceedingly fine incised lines. No basal spiral ridge.

Measurements.—Length, 9.2 mm; body whorl diameter, 3.6 mm.

Distribution.—Upper Pliocene: South Carolina; Pleistocene: Maryland to South Carolina; Recent: Massachusetts to Florida and Texas.

Occurrence in this study.—Localities 17c, 17d, 17f, 18b, 18e, 20b, 26a.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218246.

Epitonium rupicolum (Kurtz, 1860)
Plate 12, figures 3, 4

Scalaria lineata Say, 1822, p. 242 (not Röding, 1798).
Scalaria rupicola Kurtz, 1860, p. 7.
Scala lineata (Say). Dall, 1890, p. 158.
Epitonium rupicolum (Kurtz). Clench and Turner, 1952, pp. 284–287, pl. 130, figs. 1–4.
Epitonium rupicola Kurtz. [*sic*] Abbott, 1954, p. 165, pl. 22, fig. e.
Epitonium rupicolum (Kurtz). Richards, 1962, p. 73, pl. 14, figs. 20–21.

Diagnosis.—Shell small, high-spired, thin. Whorls well rounded. Basal cord present. Spiral sculpture lacking. Axial sculpture variable in strength, 12 to 16 costae per whorl. Former resting stages and outer lip may be marked by a thickened varix.

Measurements.—Length, 12.0 mm; body whorl diameter, 6.9 mm.

Distribution.—Upper Pliocene: North Carolina; Pleistocene: New Jersey to Florida and Louisiana; Recent: Massachusetts to Florida and Texas.

Occurrence in this study.—Localities 15, 17d, 17f, 18b, 18d, 18e, 20b, 26a, 29.

Type information.—Holotype: unknown. Figured hypotype: USNM 218247.

Family **MELANELLIDAE** Bartsch, 1917

Genus **MELANELLA** Bowdich, 1822

Melanella conoidea (Kurtz and Stimpson, 1851)
Plate 12, figure 5

Eulima conoidea Kurtz and Stimpson, 1851, p. 115.
Eulima conoidea Kurtz and Stimpson. Dall, 1890, p. 159, pl. 5, fig. 11.
Melanella conoidea (Kurtz and Stimpson). Olsson and Harbison, 1953, p. 333, pl. 59, fig. 7.
Melanella conoidea (Kurtz and Stimpson). Richards, 1962, p. 74, pl. 14, figs. 32–33.
?*Melanella jamaicensis* (Adams, 1845). Andrews, 1971, p. 93.

Diagnosis.—Shell small, high-spired, smooth, elongate-conic, glistening white. Aperture obliquely oval. Body whorl with a distinct angulation at the periphery.

Measurements.—Length, 2.5 mm; body whorl diameter, 0.95 mm.

Distribution.—Lower Pliocene: Virginia; Upper Pliocene: South Carolina to Florida; Pleistocene: Virginia to South Carolina; Recent: Massachusetts to the Gulf of Mexico.

Occurrence in this study.—Locality 17c.

Type information.—Holotype: unknown. Figured hypotype: USNM 218248.

Discussion.—Andrews (1971) places this species and the Western Atlantic records of *M. intermedia* (Cantraine, 1835) into synonymy under *M. jamaicensis* (Adams, 1845), but it is the authors' opinion that *M. conoidea* and *B. intermedia* should be considered morphologically distinct. *M. conoidea* is sharply angled at the periphery of the base; *M. intermedia* is evenly rounded. Abbott (1974, p. 125) recognizes all three as distinct, Western Atlantic species. Gardner (1948, pp. 209–212), and Olsson and Harbison (1953, pp. 329–335) discuss most of the numerous related Pliocene species.

Melanella intermedia (Cantraine, 1835)
Plate 12, figure 6

Eulima intermedia Cantraine, 1835, p. 390.
Eulima intermedia Cantraine. Dall, 1890, p. 159.
Melanella intermedia (Cantraine). Richards, 1962, p. 74, pl. 14, fig. 34.
?*Melanella jamaicensis* (Adams). Andrews, 1971, p. 93.

Diagnosis.—Shell small, high-spired, elongate-conic, smooth, glistening white. Aperture obliquely oval. Body whorl periphery evenly rounded.

Distribution.—Lower Pliocene: Great Britain; Upper Pliocene: Great Britain, Belgium, Italy, Florida; Pleistocene: Italy, New Jersey to Florida; Recent: Vineyard Sound to Barbados, Great Britain to the Canary Islands and the Mediterranean.

Occurrence in this study.—Localities 17c, 17d, 17f, 19a, 26a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218244.

Discussion.—(See under *M. conoidea.*)

Family **CALYPTRAEIDAE** Blainville, 1824

Genus **CRUCIBULUM** Schumacher, 1817

Crucibulum striatum (Say, 1826)
Plate 12, figure 13

Calyptraea striatum Say, 1826, p. 216.
Crucibulum striatum (Say). Dall, 1892, p. 351.
Crucibulum striatum Say. [*sic*] Abbott, 1954, p. 170, pl. 21, fig. r.
Crucibulum striatum (Say). Richards, 1962, p. 76, pl. 15, figs. 13–16, 24, 25.

Diagnosis.—Shell of moderate size, patelliform, circular; with an internal, subcircular cup. Sculpture of fairly coarse, crowded, radial threads.

Measurements.—Length, 10.5 mm; maximum diameter, 20.5 mm.

Distribution.—Pleistocene: Massachusetts to Virginia; Recent: Nova Scotia to Florida.

Occurrence in this study.—Localities 17b, 17c, 22a.

Type information.—Holotype: ANSP (missing). Figured hypotype; USNM 218252.

Discussion.—*C. constrictum* (Conrad, 1842) of the Pliocene differs in its smaller size and in having strong radiating ribs that scallop the basal margin.

Genus **CREPIDULA** Lamarck, 1799

Crepidula convexa Say, 1822
Plate 12, figures 7, 12

Crepidula convexa Say, 1822, p. 227.
Crepidula convexa Say. Dall, 1892, p. 357.
Crepidula convexa Say. Abbott, 1954, p. 171, pl. 21, fig. n.
Crepidula convexa Say. Richards, 1962, p. 76, pl. 15, fig. 23.

Diagnosis.—Shell small, slipper-shaped, highly arched and inflated; with a thin internal shelf. Shelf edge a simple, nearly straight curve; shelf extending one-third the length of the shell.

Measurements.—Length, 11.6 mm; height, 5.6 mm; maximum diameter, 7.5 mm.

Distribution.—Lower Pliocene: Virginia; Upper Pliocene: North Carolina to Florida; Pleistocene: Massachusetts to Florida, Panama; Recent: Massachusetts to Florida, Texas, and the West Indies.

Occurrence in this study.—Localities 15, 17b, 17c, 17d, 18b, 18d, 19a, 20b, 22a, 22b, 25a, 26a, 28.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218249.

Crepidula fornicata (Linné, 1758)
Plate 12, figures 8, 9

Patella fornicata Linné, 1758, p. 781.
Crepidula fornicata (Linné). Dall, 1892, p. 356.
Crepidula fornicata Linné. [*sic*] Abbott, 1954, p. 170, pl. 21, fig. m.
Crepidula fornicata (Linné). Richards, 1962, p. 76, pl. 15, figs. 21–22.

Diagnosis.—Shell of moderate size, slipper-shaped, moderately arched; with a thin internal shelf. Shelf edge sinuate; shelf extending half the length of the shell.

Measurements.—Length, 46.2 mm; height, 13.5 mm; maximum diameter, 34.5 mm.

Distribution.—Miocene: Maryland to Florida; Lower Pliocene: Virginia to Florida; Upper Pliocene: North Carolina to Costa Rica; Pleistocene: Massachusetts to Florida and Louisiana; Recent: Eastern Canada to Central America; Europe.

Occurrence in this study.—Localities 7, 13, 17b, 17c, 17f, 18a, 18b, 18c, 18e, 20a, 21a, 22a, 22b, 26a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218250.

Crepidula plana Say, 1822
Plate 12, figures 10, 11

Crepidula plana Say, 1822, p. 226.
Crepidula plana Say. Dall, 1892, p. 358.
Crepidula plana Say. Abbott, 1954, p. 172.
Crepidula plana Say. Richards, 1962, p. 76, pl. 15, fig. 17.

Diagnosis.—Shell small to moderate in size, flat to concave, smooth save for growth lines and resting stages. Internal shelf nearly straight-edged, one-third the length of the shell.

Measurements.—Length, 33.0 mm; height, 3.5 mm; maximum diameter, 26.6 mm.

Distribution.—Miocene: Maryland to Florida, Antilles?; Lower Pliocene: Virginia to Florida, Alabama?, Trinidad; Upper Pliocene: North Carolina to Florida and Venezuela; Pleistocene: Massachusetts to Florida and Louisiana, Panama; Recent: Canada to Florida and Texas, rare in West Indies, Brazil.

Occurrence in this study.—Localities 15, 17b, 17c, 17d, 17e, 17f, 18a, 18b, 18c, 18d, 18e, 19a, 20a, 20b, 22a, 22b, 25a, 26a.

Type information.—Neotype: ANSP 19495. Figured hypotype: USNM 218251.

Family **NATICIDAE** Gray, 1840
Genus **POLINICES** Montfort, 1810
Polinices duplicatus (Say, 1822)
Plate 12, figures 14, 18

Natica duplicata Say, 1822, p. 247.
Polinices (*Nevertia*) *duplicatus* (Say). Dall, 1892, pp. 368–369.
Polinices duplicatus Say. [*sic*] Abbott, 1954, p. 186, pl. 5, fig. k; pl. 22, fig. h.

Diagnosis.—Shell of moderate size, naticoid, solid, wider than high. Umbilicus covered or nearly covered by a thick callus plug. Males are smaller and more tightly coiled.

Measurements.—Length, 41.5 mm; body whorl diameter, 43.5 mm.

Distribution.—Miocene: Maryland to Florida (?); Lower Pliocene: Virginia to Florida, Louisiana and Texas; Upper Pliocene: North Carolina to Florida and Louisiana; Pleistocene: Massachusetts to Florida and Louisiana; Recent: Cape Cod to Florida and Texas.

Occurrence in this study.—Localities 12, 15, 17b, 17c, 17d, 17e, 17f, 18a, 18b, 18c, 18d, 18e, 19a, 20a, 20b, 21a, 22a, 22b, 25a, 26a, 27, 28.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218253.

Discussion.—As stated by Dall (1892) this common predator shows a wide range of shell form, varying with substrate, age, geographic location, and sex of the individual: the height-to-width ratio may vary from 1:1 to 1:2 in a single population; the umbilical callus may partially or completely close the umbilicus. Pliocene, Pleistocene, and Recent populations all show similar patterns of variation with no phylogenetic trends evident.

Genus **LUNATIA** Gray, 1847
Lunatia heros (Say, 1822)
Plate 12, figures 15, 19

Natica heros Say, 1822, p. 248.
Polinices (*Lunatia*) *heros* (Say). Dall, 1892, p. 373.
Polinices heros (Say). Johnson, 1934, p. 94.
Lunatia heros Say. [*sic*] Abbott, 1954, p. 189, fig. 22a.
Polinices heros (Say). Richards, 1962, p. 75, pl. 15, figs. 2–4, 10.

Diagnosis.—Shell moderate to large, naticoid, a little higher than wide, solid. Whorls well rounded. Umbilicus round, fairly wide, deep; not filled or covered by callus.

Measurements.—Length, 45.0 mm; body whorl diameter, 41.0 mm.

Distribution.—Miocene: (?) Maryland; Lower Pliocene: (?) Virginia to South Carolina; Pleistocene: Quebec to South Carolina; Recent: Gulf of St. Lawrence to North Carolina.

Occurrence in this study.—Localities 17b, 17c, 17d, 18a, 18b, 18c, 18d, 21a, 22a, 23, 26a.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218254.

Discussion.—*L. interna* (Say, 1824), common in the Pliocene, rarely exceeds an inch in height whereas *L. heros* attains a height of four to five inches. Specimens of similar size are easily confused but unworn specimens of *L. interna* consistently exhibit more sloping shoulders and a stronger umbilical chink. In *L. interna* the umbilicus is bordered by a strong ridge, which is absent in *L. heros.* These distinguishing features are often lost in decorticated specimens, making their identification difficult.

Lunatia triseriata (Say, 1826)
Plate 12, figures 16, 20

Natica triseriata Say, 1826, p. 211.
Polinices (*Lunatia*) *triseriata* (Say). Dall, 1892, p. 370.
Polinices triseriata (Say). Johnson, 1934, p. 94.
Lunatia triseriatus Say. [*sic*] Abbott, 1954, p. 189, pl. 22, fig. m.
Polinices triseriatus (Say). Richards, 1962, p. 75, pl. 15, fig. 29.

Diagnosis.—Shell small to moderate in size, naticoid, solid. Spire evenly tapered with three faint spiral color bands.

Measurements.—Length, 11.0 mm; body whorl diameter, 13.0 mm.

Distribution.—Upper Pliocene: Great Britain; Pleistocene: Massachusetts to Virginia; Recent: Gulf of St. Lawrence to North Carolina.

Occurrence in this study.—Locality 17c.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218255.

Genus **SINUM** Röding, 1798
Sinum perspectivum (Say, 1831)
Plate 12, figures 22, 23

Sigaretus perspectivus Say, 1831, p. 3, pl. 25.
Sigaretus perspectivus Say. Dall, 1892, pl. 378.
Sinum perspectivum (Say). Olsson and Harbison, 1953, p. 272, pl. 47, fig. 5.
Sinum perspectivum Say. [*sic*] Abbott, 1954, p. 190, pl. 22, fig. s.
Sinum perspectivum (Say). Richards, 1962, p. 76, pl. 15, fig. 12.

Diagnosis.—Shell small to moderate in size, very low, naticoid, thin. Aperture very large, flaring. Sculpture of crowded spiral threads on the dorsal surface.

Measurements.—Length, 21.0 mm; body whorl diameter, 27.0 mm.

Distribution.—Lower Pliocene: Virginia to Florida (?) and Texas; Upper Pliocene: Florida; Pleistocene: New Jersey to Florida and Louisiana, Panama; Recent: Maryland to Brazil.

Occurrence in this study.—Locality 21a.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218257.

Genus **TECTONATICA** Sacco, 1890

Tectonatica pusilla (Say, 1822)
Plate 12, figures 17, 21

Natica pusilla Say, 1822, p. 257.
Natica pusilla Say. Dall, 1892, p. 367.
Natica pusilla Say. Abbott, 1954, p. 191, pl. 22, fig. j.
Natica pusilla Say. Richards, 1962, p. 75, pl. 15, figs. 8–9.
Tectonatica pusilla (Say). Wass, 1972, p. 126.

Diagnosis.—Shell very small, naticoid, very solid. Aperture obliquely oval. Umbilicus deep, partially covered by callus.

Measurements.—Length, 3.0 mm; body whorl diameter, 3.4 mm.

Distribution.—Lower Pliocene: Virginia to Florida; Upper Pliocene: Great Britain, North Carolina to Florida and Louisiana; Pleistocene: New Jersey to Florida and Louisiana, Panama; Recent: Massachusetts to Florida, Texas, West Indies, Brazil.

Occurrence in this study.—Localities 17c, 19a.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218256.

Family **MURICIDAE** Costa, 1776

Genus **UROSALPINX** Stimpson, 1865

Urosalpinx cinerea (Say, 1822)
Plate 13, figures 1–4

Fusus cinereus Say, 1822, p. 232.
Urosalpinx cinerea Say. [*sic*] Abbott, 1954, p. 212, fig. 47e.
Urosalpinx cinerea (Say). Richards, 1962, p. 80, pl. 18, fig. 5.

Diagnosis.—Shell of moderate size, spire relatively high, siphon short but variable, being longer in juvenile specimens. Sculptured with nine to 12 axial ribs and 10 to 14 even primary spiral cords on the body whorl (excluding siphon). These primary spirals may have secondary spiral threads in the interspaces.

Measurements.—Length, 31.5 mm; body whorl diameter, 16.6 mm.

Distribution.—Miocene: Maryland (?); Upper Pliocene: Great Britain, Iceland, North Carolina (? possibly mixed Croatan); Pleistocene: Massachusetts to South Carolina and Louisiana; Recent: Nova Scotia to Southern Florida, Washington to Central California (introduced).

Occurrence in this study.—Localities 16, 17b, 17c, 17d, 17e, 17f, 18a, 18e, 22a, 22b, 25a, 26a.

Type information.—Holotype: ANSP (missing). Figured hypotypes: USNM 218261, 218262.

Discussion.—The Virginia Pliocene form, *U. phrikna* Gardner and Aldrich, 1919, and its junior synonym *U. suffolkensis* Gardner, 1948, show a relatively longer siphon, stronger sculpture, more numerous and consistent secondary spirals, and a tendency for the primary spirals to alterntae in strength, being slightly more strongly developed, when compared with *U. cinerea*.

Specimens reported from the St. Mary's Formation of Maryland as *U. cinerea* (Martin, 1904) probably represent a distinct species.

Genus **THAIS** Röding, 1798

Thais haemastoma floridana (Conrad, 1837)
Plate 13, figures 5, 10

Purpura floridana Conrad, 1837, pp. 265–266, pl. 20, fig. 21.
Thais haemastoma floridana (Conrad). Clench, 1947, p. 76, pl. 37, figs. 1–4.
Thais haemastoma floridana Conrad. [*sic*] Abbott, 1954, p. 213, pl. 25, fig. a.
Thais haemastoma floridana (Conrad). Richards, 1962, p. 80, pl. 18, figs. 10–12.

Diagnosis.—Shell large, well-inflated, solid. Sides of spire nearly straight, weakly-noded. Sculpture of low, coarse, spiral cords. Aperture large. Siphonal canal broad, short.

Measurements.—Length, 67.4 mm; body whorl diameter, 42.2 mm.

Distribution.—Pleistocene: New Jersey to Florida and Louisiana; Recent: Virginia to the West Indies, Brazil.

Occurrence in this study.—Localities 11, 17e, 17f, 18a, 18e, 20b.

Type information.—Neoholotype: MCZ 125382. Figured hypotype: USNM 218263.

Genus **EUPLEURA** Adams and Adams, 1853

Eupleura caudata (Say, 1822)
Plate 12, figures 26–29

Ranella caudata Say, 1822, p. 236.
Eupleura caudata (Say). Dall, 1890, p. 144.
Eupleura caudata Say. [*sic*] Abbott, 1954, p. 219, fig. 47b.
Eupleura caudata (Say). Richards, 1962, p. 80, pl. 18, figs. 3–4.

Diagnosis.—Shell small, rarely exceeding an inch in length; fusiform. Characterized in the adult stage by a strong, heavy varix on the outer lip; sculpture of fine spiral threads on the whorls and siphon; and about 12 strong axial ribs.

Measurements.—Length, 27.5 mm; body whorl diameter, 13.0 mm.

Distribution.—Upper Pliocene: South Carolina to Florida, Great Britain; Pleistocene: Massachusetts to

Florida and Louisiana; Recent: Massachusetts to Florida.

Occurrence in this study.—Localities 15, 17b, 17c, 17d, 17e, 17f, 18a, 18b, 18d, 19a, 20a, 20b, 21a, 22a, 22b, 25a, 26a, 27, 28.

Type information.—Holotype: ANSP (missing). Figured hypotypes: USNM 218259, 218260.

Discussion.—In some juvenile specimens, the axial ribs are finely fimbriated varices with small recurving spines at the shoulder. This form has been confused with *Boreotrophon tetricus* (Conrad, 1832b) (Pl. 12, figs. 24, 25; hypotype: USNM 218258), a species locally common in the Neogene of Virginia and Maryland. Conrad's species was illustrated as *E. caudata* juvenile, by Gardner (1948, p. 222, pl. 29, figs. 12–13), but *B. tetricus* can be differentiated by the greater constriction of the siphon, the presence of only five or six strong spiral threads on the body whorl, and the lack of strong varices in the adult.

Family **COLUMBELLIDAE** Swainson, 1840

Genus **ANACHIS** Adams and Adams, 1853

Anachis avara (Say, 1822)

Columbella avara Say, 1822, p. 230.
Anachis avara (Say). Dall, 1892, p. 135.
Anachis translirata Ravenel. [*sic*] Abbott, 1954, p. 221, pl. 25, fig. ff.
Columbella (*Anachis*) *avara* Say. Richards, 1962, p. 81, pl. 18, fig. 16.
Anachis avara (Say). Abbott, 1974, p. 195, fig. 2049.

Diagnosis.—Shell small, turriform; sculptured with 10 to 12 axial ribs on the upper half of each whorl, and with spiral threads that are strong on the base but weak or absent on the upper portions of each whorl.

Distribution.—Pleistocene: New Jersey to South Carolina and Louisiana, Panama; Recent: Massachusetts to Florida and Texas.

Occurrence in this study.—Localities of Oaks, 1964, table C-1.

Type information.—Lectotype: ANSP 16887.

Discussion.—Abbott (1954) apparently reversed figures for this and the following species.

Anachis lafresnayi (Fischer and Bernardi, 1856)
Plate 13, figures 17, 18

Columbella lafresnayi Fischer and Bernardi, 1856, p. 357, pl. 12, figs. 4, 5.
Columbella translirata Ravenel, 1861, p. 42
Anachis (*Costoanachis*) *avara translirata* (Ravenel). Gardner, 1948, p. 229, pl. 30, figs. 36–37.
Anachis avara Say. [*sic*] Abbott, 1954, pl. 25, fig. ee.
Anachis lafresnayi (Fischer and Bernardi) Abbott, 1974, p. 195, fig. 2048.

Diagnosis.—Shell small, turriform; sculptured with about 20 axial ribs and numerous spiral cords evenly distributed over the whorl.

Measurements.—Length, 17.0 mm; body whorl diameter, 7.0 mm.

Distribution.—Lower Pliocene: Virginia (?) and North Carolina; Upper Pliocene: North and South Carolina; Pleistocene: Virginia; Recent: Maine to northeast Florida, Louisiana, and the Yucatan.

Occurrence in this study.—Localities 17c, 17d, 18e, 22b, 25a, 26a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218269.

Anachis obesa (Adams, 1845)
Plate 13, figures 19, 20

Buccinum obesum Adams, 1845, p. 2.
Anachis (*Costoanachis*) *obesa* (Adams). Gardner, 1948, p. 229, pl. 30, fig. 26.
Anachis obesa Adams. [*sic*] Abbott, 1954, p. 221.
Anachis obesa (Adams). Richards, 1962, p. 80, pl. 18, figs. 14–15.

Diagnosis.—Shell very small, stubby, biconic, solid. Sculpture of sharp, narrow, axial riblets. Interspaces with spiral incised lines.

Measurements.—Length, 4.3 mm; body whorl diameter, 2.2 mm.

Distribution.—Lower Pliocene: Virginia to North Carolina; Upper Pliocene: North and South Carolina and Louisiana; Pleistocene: Virginia to Florida, Texas and Louisiana; Recent: Virginia to the West Indies and Uruguay.

Occurrence in this study.—Localities 17f, 18e, 20b.

Type information.—Lectotype: MCZ 156016. Figured hypotype: USNM 218270.

Genus **MITRELLA** Risso, 1826

Mitrella lunata (Say, 1826)
Plate 14, figures 1, 2

Nassa lunata Say, 1826, p. 213.
Astyris lunata (Say). Dall, 1890, p. 137.
Mitrella lunata (Say). Gardner, 1948, pp. 225–226, pl. 30, figs. 17–18.
Mitrella lunata Say. [*sic*] Abbott, 1954, p. 223, pl. 25, fig. gg.
Columbella (*Astyris*) *lunata* (Say). Richards, 1962, p. 81, pl. 18, figs. 22–23.

Diagnosis.—Shell very small, stubby, biconic, solid. Smooth save for a few coarse spiral threads on the siphonal canal.

Measurements.—Length, 5.4 mm; body whorl diameter, 2.5 mm.

Distribution.—Lower Pliocene: Virginia to South Carolina; Upper Pliocene: North Carolina to Florida; Pleistocene: Massachusetts to Florida and Louisiana; Recent: Massachusetts to Florida, Texas, and the West Indies.

Occurrence in this study.—Localities 11, 17b, 17c, 17d, 17e, 17f, 18a, 18b, 18d, 18e, 19a, 20a, 20b, 22a, 22b, 25a, 26a.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218271.

Family **BUCCINIDAE** Rafinesque, 1815

Genus **BUCCINUM** Linné, 1758

Buccinum undatum undatum Linné, 1758
Plate 13, figures 6, 7

Buccinum undatum Linné, 1758, p. 740.
Buccinum undatum Linné. Abbott, 1954, p. 225.
Buccinum undatum Linné. Richards, 1962, p. 81, pl. 18, fig. 24

Diagnosis.—Shell large, thin, inflated, variable. Sculpture of oblique, curving, undulatory ribs that become obsolete on the anterior half of the body whorl. Spiral sculpture of coarse, crowded threads. Aperture large, half the length of the shell.

Measurements.—Length, 60.0 mm; body whorl diameter, 38.0 mm.

Distribution.—Upper Pliocene: Great Britain; Pleistocene: Salmon River, Nova Scotia to Virginia; Recent: Arctic to off Virginia, Great Britain.

Occurrence in this study.—Localities 17b, 18b.

Type information.—Holotype: unknown. Figured hypotype: USNM 218264.

Genus **COLUS** Röding, 1798

Colus pygmaeus (Gould, 1841)
Plate 13, figures 11, 12

Fusus islandicus var. *pygmaeus* Gould, 1841, p. 284, fig. 199.
Colus pygmaea Gould. [*sic*] Abbott, 1954, p. 229, pl. 23, fig. m.

Diagnosis.—Shell small to moderate in size, fusiform, solid. Whorls six, well rounded. Aperture oval. Siphonal canal short, narrow. Sculpture of spiral lines only.

Measurements.—Unable to determine.

Distribution.—Pleistocene: Nova Scotia and Virginia; Recent: Gulf of St. Lawrence to off North Carolina.

Occurrence in this study.—Locality 17b.

Type information.—Holotype: MCZ (missing). Figured hypotype: USNM 218267.

Genus **ATRACTODON** Charlesworth, 1837

Atractodon stonei (Pilsbry, 1892)
Plate 13, figures 8, 9, 13, 14

Chrysodomus (*Sipho*) *stonei* Pilsbry, 1892, pp. 328–329.
Chrysodomus (*Sipho*) *stonei* Pilsbry, 1893, pp. 67–68, pl. 3, figs. 1–3.
Colus stonei (Pilsbry). Jacobson and Emerson, 1961, p. 62.
Neptunea stonei (Pilsbry). Richards, 1962, p. 83, pl. 19, fig. 13.
Atractodon stonei (Pilsbry). Clarke, Grant, and MacPherson, 1972, pp. 1030–1038, pl. 1.

Diagnosis.—Shell size moderate to large, reaching 75 to 80 mm; siphon straight in immature specimens, but twisting to the left with continued growth; spire, siphon, and body whorl of similar length; body whorl swollen. Sculpture consists of 24 strong spiral cords on the body whorl and siphon, diminishing in strength towards the tip of the siphon; growth lines discernable, otherwise no axial sculpture: original color probably a rich brown judging from an unusually well-preserved specimen. Initial whorl involute, void of axial sculpture; keeled with a spiral cord (at the shoulder), which is joined by four smaller threads after about one-quarter of a turn.

Measurements.—Length, 70.0 mm; body whorl diameter, 37.5 mm.

Distribution.—Lower Pliocene: Martha's Vineyard ?; Pleistocene: Nova Scotia to Cape Hatteras; Recent: Extinct.

Occurrence in this study.—Localities 17b, 17c, 18a, 18b, 19a, 22a, 23.

Type information.—Holotype: $ANSP_p$ (uncatalogued). Figured hypotypes: USNM 218265, 218266.

Discussion.—*Atractodon stonei* is an extinct species best known from beach wash from Canada to Hatteras, but most frequently reported along the New Jersey Coast. It does not seem rare, but is usually worn, broken, and overlooked. Clarke, Grant, and MacPherson (1972) suggest that the species may be a good index for the Sangamon interglacial, but Dall (1894, pp. 297, 298) reported the external mold of a closely-related form from the Lower Pliocene of Martha's Vineyard, Massachusetts.

An unusual occurrence of the species is a deep-sea core taken in 11,000 ft of water, 225 mi east of Delaware Bay in the Hudson Canyon (Richards and Ruhle, 1955), apparently carried by turbidity currents.

Clarke, Grant, and MacPherson (1972) suggest that the species inhabited an environment similar to the Acadian Province (Gulf of St. Lawrence to Cape Cod), based on the associated fauna at Salmon River, Nova Scotia. However, the Virginia specimens are associated with a fauna typical of the Virginian Subprovince, and Hatteras specimens were found with abundant *Busycon carica eliceans* (Montfort, 1810), typical of the Carolinian Province. Hence, *A. stonei* apparently had a considerable tolerance for water temperature and cannot be associated with any particular characteristic fauna for paleoenvironmental interpretations.

The nuclear whorl is rarely preserved, the above description being the first published record.

Genus **CANTHARUS** Röding, 1798

Cantharus cancellarius (Conrad, 1846)
Plate 13, figures 15, 16

Pollia cancellaria Conrad, 1846, p. 25.
Gemophos cancellatus (Conrad). Olsson and Harbison, 1953, p. 227.
Cantharus cancellaria Conrad. [*sic*] Abbott, 1954, p. 234.
Cantharus cancellaria (Conrad). Richards, 1962, p. 82, pl. 19, figs. 19–20.

Diagnosis.—Shell of moderate size, roughly biconic, thin but strong. Whorls six to seven, rounded, well inflated. Sculpture of narrow, sharp spiral and axial riblets with wider interspaces. Aperture large, constricted by a low columellar ridge at the base of the short siphonal canal.

Measurements.—Length, 23.0 mm; body whorl diameter, 12.5 mm.

Distribution.—Pleistocene: New Jersey to Florida and Louisiana; Recent: North Carolina to Yucatan.

Occurrence in this study.—Localities 17f, 18e, 20b.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218268.

Family **MELONGENIDAE** Gill, 1867

Genus **BUSYCON** Röding, 1798

Busycon canaliculatum (Linné, 1758)

Plate 14, figures 6–9

Murex canaliculatus Linné, 1758, p. 753.
Busycon (*Busycotypus*) *canaliculatum* (Linné). Wenz, 1943, p. 1219.
Busycon canaliculatum Linné. [*sic*] Abbott, 1954, p. 236, pl. 23, fig. n.
Busycon (*Busycotypus*) *canaliculatum* (Linné). Hollister, 1958, pp. 94–95, pl. 14, figs. 1–8.
Busycon canaliculatum (Linné). Richards, 1962, p. 83, pl. 19, figs. 16, 21.

Diagnosis.—Shell very large, thin but strong, pyriform. Suture with a deep, wide channel. Periphery of the shoulder keeled; keel commonly beaded or noded on the early whorls. Sculpture of flat spiral cords. Aperture very large. Siphonal canal long, rather narrow.

Measurements.—Adult: Length, 200.0 mm; body whorl diameter, 115.0 mm. Juvenile: Length, 63.0 mm; body whorl diameter, 28.5 mm.

Distribution.—Lower Pliocene: Virginia (?); Upper Pliocene: South Carolina; Pleistocene: New York to South Carolina and Louisiana; Recent: Massachusetts to Florida.

Occurrence in this study.—Localities 11, 16, 17b, 17c, 17d, 18a, 18b, 18c, 18d, 19a, 21a, 22a, 25a, 26a, 27, 28.

Type information.—Holotype: LS 555. Figured hypotypes: USNM 218274, 218275.

Discussion.—*B. incile* (Conrad, 1833) of the Pliocene is a more swollen shell with the siphon constricted closer to the base of the body whorl, giving the appearance of a longer, narrower siphon; its suture and shoulder carinae also tend to be more accentuated than in *B. canaliculatum*.

Busycon carica (Gmelin, 1791)

Plate 14, figures 3–5

Murex carica Gmelin, 1791, p. 3545.
Busycon carica Gmelin. [*sic*] Abbott, 1954, p. 235, pl. 23, fig. i.
Busycon aruanum (Linné). Hollister, 1958, pp. 70–78, pl. 8, figs. 1–3, 5–11; pl. 18, figs. 3–5.
Busycon carica (Gmelin). Richards, 1962, p. 83, pl. 20, fig. 1.

Diagnosis.—Shell very large, heavy, strong, subpyriform. Shoulder marked by large nodes. Aperture large. Outer lip rather thin, commonly broken and repaired. Siphonal canal long, broad.

Measurements.—Adult: Length, 127.0 mm; body whorl diameter, 64.0 mm. Juvenile: Length, 52.0 mm; body whorl diameter, 22.0 mm.

Distribution.—Pleistocene: New Jersey to South Carolina; Recent: Massachusetts to Florida.

Occurrence in this study.—Localities 11, 15, 17b, 17c, 17d, 17e, 18a, 18b, 18c, 18d, 20b, 21a, 22a, 25a, 26a, 27, 28.

Type information.—Holotype: unknown. Figured hypotypes: USNM 218272, 218273.

Discussion.—Hollister (1958) contends that this species is the one intended by Linné's *Murex aruanum* rather than the Australian Trumpet customarily so assigned, but most current authorities recognize the traditional designations. *B. tritone* (Conrad, 1862) of the Virginia Pliocene resembles this species, but can be separated by its swollen siphon, its tendency to develop internal spiral lirations on the lip, its development of the resting stages into sharp, thin varices, and its consistent sharpness of the shoulder spines. *B. tritone* may be a subspecies of *B. maximum* (Conrad, 1840), a Pliocene form possessing the swollen siphon but having a smooth rounded shoulder and no development of varices.

Busycon carica eliceans (Montfort, 1810)

Fulgur eliceans Montfort, 1810, p. 502–504, fig. 126.
Busycon eliceans (Montfort). Hollister, 1958, pp. 80–83, pl. 10, figs. 1–5, 10, 11; pl. 18, fig. 1, 2, 4, 6.
Busycon carica eliceans (Montfort). Abbott, 1968, pp. 138–139, fig. 2.

Diagnosis.—Shell as in *B. carica*, but with fewer and much larger nodes, and a swollen ridge at the base of the siphonal canal.

Distribution.—Pleistocene: Virginia and North Carolina; Recent: North Carolina to Northeast Florida.

Occurrence in this study.—Locality 17e.

Type information.—Neotype: PRI 24941.

Busycon contrarium (Conrad, 1840)

Plate 14, figures 11, 12

Fulgur contrarius Conrad, 1840, p. 387.
Fulgur perversum Dall, 1890, p. 116 (not of Linné, 1758).
Busycon contrarium (Conrad). Olsson and Harbison, 1953, pp. 210–211.
Busycon contrarium Conrad. [*sic*] Abbott, 1954, p. 236, pl. 23, fig. o.
Busycon sinistrum Hollister, 1958, p. 85, pl. 11, figs. 1–4, 10, 12; pl. 12, fig. 11.
Busycon perversum Richards, 1962, p. 83, pl. 19, figs. 15–22 (not of Linné, 1758).

Diagnosis.—Shell as in *B. carica*, but sinistral.

Measurements.—Length, 34.9 mm; body whorl diameter, 16.3 mm.

Distribution.—Lower Pliocene: North Carolina to Florida; Upper Pliocene: North Carolina to Florida. Pleistocene: New Jersey to South Carolina; Recent: New Jersey to Texas.

Occurrence in this study.—Localities 10, 11, 17d.

Type information.—Holotype: $ANSP_p$ 14295. Figured hypotype: USNM 218276.

Family **NASSARIIDAE** Iredale, 1916

Genus **NASSARIUS** Dumeril, 1806

Nassarius acutus (Say, 1822)
Plate 14, figures 10, 15

Nassa acuta Say, 1822, p. 234.
Nassarius acutus Say. [*sic*] Abbott, 1954, p. 237, fig. 53c.
Nassarius acutus (Say). Richards, 1962, p. 81, pl. 18, fig. 17.

Diagnosis.—Shell small, high-spired, solid. Sculpture of coarsely-noded spiral riblets. Suture channeled. Aperture circular; outer lip thickened. Siphonal canal constricted, very short.

Measurements.—Length, 10.2 mm; body whorl diameter, 5.2 mm.

Distribution.—Lower Pliocene: Texas; Upper Pliocene: Louisiana; Pleistocene: New Jersey to Georgia and Louisiana; Recent: Virginia to Florida and Texas.

Occurrence in this study.—Localities 15, 17c, 17d, 17e, 17f, 18b, 18d, 18e, 19a, 20b, 26a.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218277.

Subgenus **ILYANASSA** Stimpson, 1865

Nassarius (Ilyanassa) obsoletus (Say, 1822)
Plate 14, figures 16, 17

Nassa obsoleta Say, 1822, p. 232.
Ilyanassa obsoleta (Say). Dall, 1892, p. 239.
Nassarius (*Ilyanassa*) *obsoletus* Say. [*sic*] Abbott, 1954, p. 240, pl. 23, fig. p.
Nassarius obsoletus (Say). Richards, 1962, p. 81, pl. 18, figs. 18, 20, 21.

Diagnosis.—Shell small, solid, inflated. Sculpture of numerous, distinct to obsolete spiral threads. Spire commonly eroded. Columella with an oblique fold low in the aperture.

Measurements.—Length, 18.1 mm; body whorl diameter, 11.0 mm.

Distribution.—Upper Pliocene: South Carolina; Pleistocene: Massachusetts to South Carolina; Recent: Gulf of St. Lawrence to Florida.

Occurrence in this study.—Localities 11, 13, 17b, 17c, 17d, 17e, 17f, 18a, 18e, 20b, 21a, 22a, 22b, 25a, 26a, 28.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218279.

Subgenus **HINIA** Gray, 1847

Nassarius (Hinia) trivittatus (Say, 1822)
Plate 14, figures 14, 21

Nassa trivittata Say, 1822, p. 231.
Nassarius (*Hinia*) *trivittatus* Say. [*sic*] Abbott, 1954, p. 239, pl. 23, fig. j.
Nassarius trivittatus (Say). Richards, 1962, p. 81, pl. 18, fig. 19.

Diagnosis.—Shell small, thin, easily broken. Sculpture cancellate, with 20 to 25 sharp axial riblets cut by incised spiral lines. Aperture oval. Siphonal canal short, twisted.

Measurements.—Length, 21.6 mm; body whorl diameter, 12.0 mm.

Distribution.—Upper Pliocene: Iceland, North Carolina; Pleistocene: Great Britain, Massachusetts to South Carolina; Recent: Gulf of St. Lawrence to Florida.

Occurrence in this study.—Localities 11, 12, 15, 17b, 17c, 17d, 18a, 18b, 18d, 19a, 20a, 20b, 21a, 22a, 22b, 23, 25a, 26a, 27, 28, 29.

Type information.—Holotype: ANSP 16472. Figured hypotype: USNM 218280.

Nassarius vibex (Say, 1822)
Plate 14, figures 13, 20

Nassa vibex Say, 1822, p. 231.
Nassa vibex Say. Dall, 1890, p. 132.
Uzita vibex (Say). Gardner, 1948, p. 253, pl. 30, fig. 23.
Nassarius vibex Say. [*sic*] Abbott, 1954, p. 237, pl. 23, fig. q.
Nassarius vibex (Say). Richards, 1962, p. 81, pl. 18, fig. 13.

Diagnosis.—Shell small, solid, stubby. Spire conic, projecting. Body whorl inflated. Aperture large, with a large parietal shield. Sculpture of beaded spiral cords.

Measurements.—Length, 14.8 mm; body whorl diameter, 9.7 mm.

Distribution.—Lower Pliocene: North and South Carolina; Upper Pliocene: North Carolina to Florida; Pleistocene: New York to Florida, and Louisiana, Panama; Recent: Boston Harbor, Massachusetts to Florida and the West Indies.

Occurrence in this study.—Localities 11, 17d, 17e, 17f, 18e, 20b, 25a, 26a.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218278.

Family **OLIVIDAE** Latreille, 1825

Genus **OLIVA** Bruguière, 1789

Oliva sayana Ravenel, 1834
Plate 14, figures 18, 19

Oliva litterata Lamarck, 1822, p. 425 (not of Bolten, 1798).
Oliva sayana Ravenel, 1834, p. 19.
Oliva litterata Lamarck. Dall, 1890, p. 44
Oliva sayana Ravenel. Abbott, 1954, p. 245, pl. 12, fig. a.
Oliva sayana Ravenel. Richards, 1962, p. 85, pl. 21, fig. 1.

Diagnosis.—Shell of moderate size, solid, cylindrical, smooth and highly polished. Spire very short. Aperture long, narrow. Outer lip thin.

Measurements.—Length, 21.5 mm; body whorl diameter, 10.5 mm.

Distribution.—Upper Pliocene: North and South Carolina (?); Pleistocene: Virginia to Florida; Recent: North Carolina to Texas, Brazil.

Occurrence in this study.—Localities 17b, 17c, 18b, 23.

Type information.—Holotype: unknown. Figured hypotype: USNM 218281.

Discussion.—The lower Pliocene species, *O. canaliculata* Lea, 1843, is more obovate due to a flaring of the anterior canal and the lip, and its sutures are more strongly grooved than the larger, more tightly-coiled *O. sayana.* The columellar threads and parietal callus are generally more distinct in *O. canaliculata.*

Genus **OLIVELLA** Swainson, 1831

Olivella mutica (Say, 1822)
Plate 14, figures 22, 23

Oliva mutica Say, 1822, p. 228
Olivella mutica (Say). Dall, 1890, p. 45.
Olivella mutica Say. [*sic*] Abbott, 1954, p. 246, pl. 22, fig. v.
Olivella mutica (Say). Richards, 1962, p. 85, pl. 21, figs. 11–12.

Diagnosis.—Shell small, solid, subcylindrical, smooth and highly polished. Spire high, conic.

Measurements.—Length, 15.0 mm; body whorl diameter, 6.5 mm.

Distribution.—Lower Pliocene: Virginia to Florida and Santo Domingo, Texas; Upper Pliocene: North Carolina to Florida and Louisiana; Pleistocene: New Jersey to Florida and Louisiana; Recent: New Jersey to Texas and the West Indies.

Occurrence in this study.—Localities 12, 15, 17b, 17c, 17d, 18a, 18c, 18d, 18e, 19a, 20a, 20b, 21a, 22a, 22b, 25a, 26a, 27.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218282.

Family **MARGINELLIDAE** Fleming, 1828

Genus **DENTIMARGO** Cossmann, 1899

Dentimargo aureocincta (Stearns, 1873)
Plate 15, figures 1, 2

Marginella aureocincta Stearns, 1873, p. 22.
Marginella aureocincta Stearns. Dall, 1890, p. 52.
Marginella aureocincta Stearns. Abbott, 1954, p. 254, fig. 56b.
Volvarinella aureocincta (Stearns). Coan and Roth, 1966, p. 290.
Dentimargo aureocincta (Stearns). Coan and Roth *in* Keen, 1971, p. 636.

Diagnosis.—Shell very small, solid, biconic, smooth and highly polished. Spire high. Columella with four folds.

Measurements.—Length, 4.7 mm; body whorl diameter, 2.2 mm.

Distribution.—Lower Pliocene: Virginia to Florida; Upper Pliocene: North Carolina to Florida; Pleistocene: Virginia to Florida; Recent: Virginia to the West Indies, Brazil.

Occurrence in this study.—Localities 17b, 17c, 18b, 18d, 26a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218283.

Genus **PRUNUM** Herrmannsen, 1852

Prunum roscidum (Redfield, 1860)
Plate 15, figures 3, 4

Marginella roscidia Redfield, 1860, p. 174.
Marginella limatula Conrad. Dall, 1890, pp. 49–50.
Marginella limatula Conrad. Johnson, 1934, p. 131.
Prunum limatula Conrad. [*sic*] Abbott, 1954, p. 257, fig. 56f.
Marginella roscidia Redfield. Abbott, 1957, pp. 52–53, pl. 4, figs. 4–4a.
Prunum roscidum (Redfield). Richards, 1962, p. 85, pl. 21, fig. 10.

Diagnosis.—Shell small, solid, smooth and highly polished. Spire short, stubby. Columella with four oblique folds.

Measurements.—Length, 15.2 mm; body whorl diameter, 9.6 mm.

Distribution.—Lower Pliocene: Virginia to Florida; Upper Pliocene: North Carolina to Florida; Pleistocene: Virginia to Florida; Recent: New Jersey to Florida.

Occurrence in this study.—Localities 15, 17b, 17c, 17d, 18a, 18b, 18d, 19a, 20a, 21a, 22b, 25a, 26a, 27.

Type information.—Holotype: unknown. Figured hypotype: USNM 218284.

Discussion.—This species has been frequently united with *Prunum limatulum* (Conrad, 1834) of the Pliocene of Virginia, but Abbott (1957) states that the forms are distinct. The Pliocene shells are slightly smaller, and when color pattern is preserved, it is a little coarser. Uppermost Yorktown specimens, however, cannot be so easily distinguished and the question is not presently resolved. The Pliocene ranges given here are based on *P. limatula.*

Genus **GRANULINA** Jousseaume, 1875

Granulina ovuliformis (d'Orbigny, 1842)
Plate 15, figures 5, 6

Marginella ovuliformis d'Orbigny, 1842, p. 101, pl. XX, figs. 33–35.
Marginella lacrimula Gould, 1862, p. 281.
Cypraeolina lacrimula (Gould). Gardner, 1948, p. 263, pl. 38, figs. 20–21.
Gibberulina ovuliformis d'Orbigny. [*sic*] Abbott, 1954, p. 259, fig. 56o.
Cypraeolina ovuliformis (d'Orbigny). Coan and Roth, 1966, p. 295.

Bullata ovuliformis (d'Orbigny). Abbott, 1968, p. 156.
Granulina ovuliformis (d'Orbigny). Coan and Roth, 1971, p. 638.

Diagnosis.—Shell minute, solid, cypraeiform, smooth and polished. Spire involute, covered over by the arching aperture.

Measurements.—Length, 2.3 mm; body whorl diameter, 1.2 mm.

Distribution.—Upper Pliocene: North Carolina to Florida; Pleistocene: Virginia to Florida; Recent: Virginia to Florida and the West Indies, Brazil.

Occurrence in this study.—Locality 17d.

Type information.—Holotype: unknown. Figured hypotype: USNM 218285.

Family **TEREBRIDAE** Adams and Adams, 1854

Genus **TEREBRA** Bruguière, 1789

Terebra concava (Say, 1827)
Plate 15, figures 7, 8

Turritella concava Say, 1827, p. 207.
Terebra concava (Say). Dall, 1890, p. 24.
Terebra (*Strioterebrum*) *concava* (Say). Gardner, 1948, p. 277, pl. 38, fig. 32.
Terebra concava Say. [*sic*] Abbott, 1954, p. 266, pl. 26, fig. j.
Terebra concava (Say). Richards, 1962, p. 85, pl. 21, fig. 8.

Diagnosis.—Shell small, very elongate, high-spired, solid. Whorls concave between sutures. Sculpture of spiral threads and with a strong, noded cord just above the suture. Siphonal canal short, obliquely twisted.

Measurements.—Length, 19.8 mm; body whorl diameter, 4.8 mm.

Distribution.—Lower Pliocene: Virginia to South Carolina and Texas; Upper Pliocene: North Carolina to Florida; Pleistocene: New Jersey to Florida; Recent: North Carolina to Florida, Brazil.

Occurrence in this study.—Localities 17b, 17c, 17f, 18a, 18b, 18c, 18d, 18e, 19a, 20b, 26a.

Type information.—Holotype: ANSP (missing). Figured hypotype: USNM 218286.

Terebra dislocata (Say, 1822)
Plate 15, figures 9, 25

Cerithium dislocata Say, 1822, p. 235.
Terebra dislocata (Say). Dall, 1890, p. 24.
Terebra dislocata Say. [*sic*] Abbott, 1954, p. 265, pl. 26, fig. i.
Terebra dislocata (Say). Richards, 1962, p. 85, pl. 21, figs. 2–3.

Diagnosis.—Shell of moderate size, very elongate, high-spired. Whorls slightly inflated, not concave. Sculpture of narrow axial riblets with wider interspaces, and crowded spiral incised lines. A single spiral groove interrupts the sculpture pattern at or a little above mid-whorl.

Measurements.—Length, 28.0 mm; body whorl diameter, 18.0 mm.

Distribution.—Pleistocene: New Jersey to Florida and Louisiana; Recent: Maryland to Florida and Texas, Brazil, California to Panama.

Occurrence in this study.—Localities 17b, 17c, 17e, 18a, 18b, 18d, 18e, 19a, 20a, 26a.

Type information.—Holotype: ANSP 192924. Figured hypotype: USNM 218287.

Discussion.—The Pliocene species *T. carolinensis* Conrad, 1841, averages a bit larger, has finer sculpture, and has three or four strongly-incised lines on the base as opposed to a single strong line for *T. dislocata.*

Family **TURRIDAE** Swainson, 1840

Genus **KURTZIELLA** Dall, 1918

Kurtziella cerina (Kurtz and Stimpson, 1851)
Plate 15, figures 10, 11

Pleurotoma cerinum Kurtz and Stimpson, 1851, p. 11.
Mangelia cerina (Kurtz and Stimpson). Johnson, 1934, p. 141.
Pseudoraphitoma (*Kurtziella*) *cerina* (Kurtz and Stimpson). Wenz, 1943, p. 144, fig. 4076.
Mangelia cerina (Kurtz and Stimpson). Richards, 1962, p. 86, pl. 21, fig. 6.

Diagnosis.—Shell small, reaching 6 mm in length, turriform; shoulders sharply angled, notch between suture and shoulder, sutures scalloped by longitudinal ribs; sculpture of fourteen longitudinal ribs passing the length of the shell, and of numerous spiral incised lines.

Measurements.—Length, 4.8 mm; body whorl diameter, 1.9 mm.

Distribution.—Upper Pliocene: North and South Carolina; Pleistocene: New Jersey to South Carolina and Louisiana; Recent: Massachusetts to Florida, Yucatan.

Occurrence in this study.—Localities 17b, 17c, 18b, 18d, 18e, 19a, 20b, 21a, 26a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218288.

Genus **BRACHYCYTHARA** Woodring, 1928

Brachycythara galae dimonia Fargo, 1953
Plate 15, figures 12, 13

Brachycythara galae dimonia Fargo *in* Olsson and Harbison, 1953, p. 389, pl. 20, fig. 6.

Diagnosis.—

Shell small, slender, rather variable . . . biconic, subturreted spire not inflated, apex blunt, whorls angular at the periphery, constricted to appressed sutures. The shoulders steeply sloping more than half the height of the whorls . . . . The conch is dominated by low, narrow, rounded, widely-spaced axial ribs (9–11). The entire surface of the conch is covered with fine, flattened spiral cords, which particularly on the periphery and the one beneath the suture are stronger (Fargo, 1953, p. 389).

Measurements.—Length, 8.6 mm; body whorl diameter, 3.6 mm.

Distribution.—Upper Pliocene: South Carolina to Florida; Pleistocene: Virginia; Recent: Extinct.

Occurrence in this study.—Locality 19a.

Type information.—Holotype: $ANSP_p$ 19151. Figured hypotype: USNM 218289.

Family **PYRAMIDELLIDAE** Gray, 1840

Genus **LONGCHAEUS** Mörch, 1875

Longchaeus arenosa (Conrad, 1844)
Plate 15, figures 14, 15

Pyramidella arenosa Conrad, 1844, p. 309.
Obeliscus crenulatus Holmes, 1860, p. 88, pl. 13, figs. 14, 14a.
Pyramidella crenulata (Holmes). Dall, 1892, pp. 247–248.
Pyramidella crenulata (Holmes). Richards, 1962, p. 74, pl. 14, fig. 35.
Pyramidella crenulata (Holmes). Abbott, 1968, p. 175, fig. 2.

Diagnosis.—Shell length reaching about 2.5 cm, turriform; smooth with sutures impressed, finely crenulated along margin of suture channel on one or both sides; aperture oval, three columellar plaits.

Measurements.—Length, 9.0 mm; body whorl diameter, 3.1 mm.

Distribution.—Lower Pliocene: Virginia and North Carolina; Upper Pliocene: North Carolina to Florida; Pleistocene: Virginia to Florida and Louisiana; Recent: South Carolina to Florida and the West Indies.

Occurrence in this study.—Localities 17d, 22b, 26a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218290.

Discussion.—As stated by Dall (1892, p. 247), Conrad's lower Pliocene species cannot effectively be separated from the Recent forms; and his name has priority over the more familiar "*crenulata*" by seventeen years. As seems to be the case with most pyramidellids, the size of the adult varies greatly, ranging from 0.5 cm to 3 cm in fossil specimens.

Genus **EULIMASTOMA** Bartsch, 1916

Eulimastoma cf. **E. weberi** (Morrison, 1965)
Plate 15, figure 16

Diagnosis.—Shell minute, smooth with sutures impressed, whorls slightly constricted above and broadened below the suture giving the shell a "Christmas tree" outline; three columellar plaits.

Measurements.—Length, 2.6 mm; body whorl diameter, 1.0 mm.

Distribution.—Pleistocene: Virginia.

Occurrence in this study.—Locality 20b.

Type information.—Holotype: unknown. Figured hypotype: USNM 218291.

Discussion.—Identification of this species is uncertain. Andrews (1977, p. 175) figures a very similar specimen as *Eulimastoma* cf. *E. weberi* (Morrison, 1965), a species cited as about one-half the size of our fossil form.

Genus **ODOSTOMIA** Fleming, 1813

Odostomia (Sayella) fusca (Adams, 1839)
Plate 15, figure 27

Pyramis fusca Adams, 1839, p. 282, pl. 4, fig. 9.
Odontostomia (*Syrnola*) *fusca* (Adams). Dall, 1892, pp. 251–252.
Pyramidella (*Syrnola*) *fusca* Adams. [*sic*] Abbott, 1954, p. 288, fig. 62e.
Sayella fusca (Adams). Abbott, 1968, p. 174, fig. 4.

Diagnosis.—Shell small, 3 mm in length, turriform, smooth with whorls slightly inflated; suture distinct, aperture spatulate, no observable columellar plait.

Measurements.—Length, 1.1 mm; body whorl diameter, 1.0 mm.

Distribution.—Upper Pliocene: North Carolina to Florida; Pleistocene: Massachusetts to Florida; Recent: Massachusetts to Florida and the Gulf of Mexico.

Occurrence in this study.—Localities 17c, 19a, 20b.

Type information.—Lectotype: MCZ 156006. Figured hypotype: USNM 218298.

Odostomia dianthophila Wells and Wells, 1961
Plate 15, figure 26

Odostomia (*Chrysallida*) *dianthophila* Wells and Wells, 1961, pp. 149–157, figs. 1–3.

Diagnosis.—Shell minute, less than 2 mm in length, sub-turbinate with smooth, flattened protoconch; postnuclear whorls evenly coiled throughout; varices wanting; crenulate axial ribs intersected by weak spiral threads; ovate aperture half the height of body whorl; peritreme continuous.

Measurements.—Length, 1.4 mm; body whorl diameter, 0.7 mm.

Distribution.—Pleistocene: Virginia, Delaware; Recent: Massachusetts to North Carolina.

Occurrence in this study.—Locality 20b.

Type information.—Holotype: USNM 613499. Figured hypotype: USNM 218297.

Discussion.—This minute species is parasitic on the serpulid annelid *Eupomatus dianthus* (Verrill and Smith, 1873), hence the specific name.

Odostomia gibbosa Bush, 1909
Plate 15, figure 20

Odostomia gibbosa Bush, 1909, p. 482.
Odostomia (*Odostomia*) *gibbosa* Bush. Abbott, 1954, p. 288, fig. 62k.
Odostomia gibbosa Bush. Abbott, 1974, p. 292, fig. 3474.

Diagnosis.—Shell small, moderately turriform, but unusually broad for the genus; body whorl particularly swollen in most specimens; smooth except for growth lines; aperture ovate, umbilicus small but very deep; a single very strong columellar plait is present.

Measurements.—Length, 3.4 mm; body whorl diameter, 2.0 mm.

Distribution.—Pleistocene: Virginia; Recent: Maine to Florida and Texas.

Occurrence in this study.—Localities 17d, 18d, 19a.

Type information.—Holotype: USNM 203812. Figured hypotype: USNM 218294.

Odostomia impressa (Say, 1822)
Plate 15, figures 21, 22

Turritella impressa Say, 1822, p. 244.
Odontostomia impressa (Say). Dall, 1892, p. 251.
Odostomia (*Menestho*) *impressa* Say. [*sic*] Abbott, 1954, p. 288, fig. 62i.
Odostomia impressa (Say). Richards, 1962, p. 75.

Diagnosis.—Shell minute, elongate, high-spired. Dominant sculpture of low, flat spiral threads. Interspaces channeled, with microscopic axial lines. Aperture oval.

Measurements.—Length, 3.2 mm; body whorl diameter, 1.3 mm.

Distribution.—Upper Pliocene: South Carolina to Florida; Pleistocene: Massachusetts to South Carolina; Recent: Massachusetts to Florida.

Occurrence in this study.—Localities 17d, 17e, 17f, 18e, 20b, 26a.

Type information.—Holotype: ANSP 19988. Figured hypotype: USNM 218295.

Odostomia seminuda (Adams, 1839)
Plate 15, figures 23, 24

Jaminia seminuda Adams, 1839, p. 280, pl. 4, fig. 13.
Odontostomia seminuda (Adams). Dall, 1892, p. 251.
Odostomia (*Chrysallida*) *seminuda* Adams. [*sic*] Abbott, 1954, p. 288, fig. 62j.
Odostomia seminuda (Adams). Richards, 1962, p. 75.

Diagnosis.—Shell minute, less than 2 mm in length, turriform; sculptured with about a dozen spiral ribs on the body whorl, the upper four of which are incised by longitudinal lines giving the upper portion of the whorl a cancellate appearance; aperture ovate; single columellar plait.

Measurements.—Length, 4.4 mm; body whorl diameter, 1.8 mm.

Distribution.—Upper Pliocene: North Carolina to Florida; Pleistocene: Massachusetts to Florida; Recent: Prince Edward Island to Florida and the Gulf of Mexico.

Occurrence in this study.—Localities 17d, 17e, 17f, 18e, 26a.

Type information.—Lectotype: MCZ 186052. Figured hypotype: USNM 218296.

Genus **TURBONILLA** Risso, 1826

Turbonilla interrupta (Totten, 1835)
Plate 15, figures 17, 18

Turritella interrupta Totten, 1835, pp. 347–353.
Turbonilla interrupta (Totten). Dall, 1892, pp. 259–260.
Turbonilla interrupta (Totten). Abbott, 1974, p. 305, fig. 3754.

Diagnosis.—Shell reaching eight mm or more in length, turriform and very slender, having some 20 prominent longitudinal ribs and numerous spiral incised lines or threads; aperture ovate with no discernable columellar plaits.

Measurements.—Length, 7.4 mm; body whorl diameter, 1.9 mm.

Distribution.—Lower Pliocene: Virginia? and North Carolina?; Upper Pliocene: North Carolina? to Florida?; Pleistocene: Nantucket, Massachusetts to Florida and Louisiana; Recent: Nova Scotia to Florida, Texas and the West Indies.

Occurrence in this study.—Localities 17b, 17c, 17d, 17e, 17f, 18b, 18d, 18e, 19a, 20b, 22a, 22b, 25a, 26a.

Type information.—Holotype: unknown. Figured hypotype: USNM 218292.

Discussion.—This species is frequently cited in the Pliocene literature, but we have seen it with certainty only from late Pleistocene and Recent faunas.

Turbonilla puncta (Adams, 1850)

Chemnitzia puncta Adams, 1850, p. 72.
Turbonilla puncta (Adams). Dall, 1892, p. 256.
Turbonilla puncta (Adams). Richards, 1962, p. 75.
Turbonilla puncta (Adams). Abbott, 1974, p. 306, fig. 3775.

Diagnosis.—Shell very small, very elongate, high-spired. Whorls gently rounded. Axial sculpture dominant, of 20 to 24 thick, slightly sinuous ribs with narrow, deep interspaces. Spiral lines in interspaces only. Spaces between spiral and axial sculpture deeply pitted. Base of shell with fine spiral lines only. Aperture oval.

Distribution.—Upper Pliocene: Florida; Pleistocene: Virginia; Recent: North Carolina to Haiti and Jamaica.

Occurrence in this study.—Locality 15.

Type information.—Holotype: MCZ (lost).

Discussion.—This species is cited without reference from the literature by Richards (1962, p. 75), and has not been rediscovered by subsequent workers.

Turbonilla reticulata (Adams, 1850)
Plate 15, figure 19.

Chemnitzia reticulata Adams, 1850, p. 75.
Turbonilla reticulata (Adams). Dall, 1892, pp. 260–261.
Turbonilla reticulata (Adams). Woolman, 1898, p. 418.
Turbonilla reticulata (Adams). Richards, 1962, p. 75.

Diagnosis.—Shell very small, rarely exceeding 4 mm in length, turriform and very slender; about 16 longitudinal ribs with numerous spiral lines or threads in the interspaces; whorls slightly inflated; aperture ovate.

Measurements.—Length, 2.5 mm; body whorl diameter, 0.9 mm.

Distribution.—Upper Pliocene: North Carolina to Florida; Pleistocene: Virginia to South Carolina; Recent: North Carolina to Florida and the West Indies.

Occurrence in this study.—Locality 20b.

Type information.—Holotype: MCZ (lost). Figured hypotype: USNM 218293.

Discussion.—This species much resembles a small *T. interrupta* (Totten, 1835) with accentuated spiral sculpture. *T. reticulata* does consistently have fewer longitudinal ribs and more inflated whorls.

Family **ACTEONIDAE** d'Orbigny, 1842

Genus **RICTAXIS** Dall, 1871

Rictaxis punctostriatus (Adams, 1840)
Plate 15, figures 28, 29

Tornatella punctostriata Adams, 1840, p. 323, pl. 3, fig. 9.
Actaeon punctostriata (Adams). Dall, 1890, p. 14.
Acteon punctostriatus (Adams). Olsson and Harbison, 1953, pp. 157–158.
Acteon punctostriatus Adams. [*sic*] Abbott, 1954, p. 275, pl. 26, fig. t.
Rictaxis punctostriatus (Adams). Marcus, 1972, pp. 300–301.

Diagnosis.—Shell minute, thin, very fragile. Whorls inflated. Spire short in juvenile shells, more elevated with continued growth. Sculpture of incised, punctate spiral lines. Columella with a single fold.

Measurements.—Length, 1.0 mm; body whorl diameter, 0.7 mm.

Distribution.—Upper Pliocene: North Carolina to Florida; Pleistocene: Virginia to Florida; Recent: Massachusetts to Florida.

Occurrence in this study.—Localities 17f, 18e, 20b.

Type information.—Holotype: MCZ 155925. Figured hypotype: USNM 218299.

Discussion.—All specimens are juvenile but agree well with Recent specimens from Sand Bridge, Virginia. *A. novellus* Conrad, 1834, is a larger form from the Pliocene that has spiral lines covering the entire body whorl; in *R. punctostriatus* the adult form restricts these lines to the lower portion of the body whorl. The specimen figured by Abbott (1954, pl. 26, fig. t) is unusually high spired.

Family **CYLICHNIDAE** Adams and Adams, 1854

Genus **ACTEOCINA** Gray, 1847

Acteocina canaliculata (Say, 1826)
Plate 15, figures 35–37

Volvaria canaliculata Say, 1826, p. 211.
Acteocina canaliculata (Say). Olsson and Harbison, 1953, p. 159, pl. 25, figs. 6–6b.
Retusa canaliculata Say. [*sic*] Abbott, 1954, p. 280, pl. 26, fig. x.
Acteocina canaliculata (Say), Abbott, 1974, p. 313, fig. 3937.

Diagnosis.—Shell small, reaching 7 mm in length, cylindrical, smooth except for growth lines; spire somewhat elevated with the embryonic whorl rotated 90 degrees, perpendicular to the longitudinal axis of the shell; aperture spatulate, with a single columellar plait.

Measurements.—Length, 4.0 mm; body whorl diameter, 1.9 mm.

Distribution.—Miocene: New Jersey to Florida (?); Lower Pliocene: Virginia to Florida and Texas; Upper Pliocene: North Carolina to Florida; Pleistocene: New York to Florida and Louisiana, Panama; Recent: Nova Scotia to Florida, Texas, and the West Indies.

Occurrence in this study.—Localities 15, 17b, 17c, 17d, 17e, 17f, 18a, 18b, 18d, 18e, 19a, 21a, 22a, 22b, 25a, 26a, 29.

Type information.—Holotype ANSP (missing). Figured hypotype: USNM 218302.

Discussion.—Except for differences of the initial whorl there is little to distinguish between *A. canaliculata,* and *Retusa obtusa* (Montagu, 1808). The spire of *A. canaliculata* is somewhat elevated and completely visible, but that of *R. obtusa* is flattened with involute nuclear whorls.

Family **RETUSIDAE** Thiele, 1925

Genus **RETUSA** Brown, 1827

Retusa obtusa (Montagu, 1808)
Plate 15, figures 32–34

Bulla obtusa Montagu, 1808, pp. 223–224, pl. 7, fig. 3.
Bulla pertenuis Mighels, 1842, p. 346.
Retusa obtusa Montagu. [*sic*] Abbott, 1954, p. 280, fig. 59a.
Retusa pertenuis (Mighels). Richards, 1962, p. 86, pl. 16, fig. 11.

Diagnosis.—Shell small, reaching 6 mm in length, cylindrical and smooth, except for growth lines; spire depressed, embryonic whorl involute, ultradextral; aperture spatulate, with a single columellar plait.

Measurements.—Length, 4.0 mm; body whorl diameter, 2.3 mm.

Distribution.—Upper Pliocene: Great Britain; Pleistocene: Quebec and Virginia; Recent: Greenland to Florida (10 to 294 fathoms).

Occurrence in this study.—Locality 20b (also localities of Oaks, 1964, table C-1).

Type information.—Syntypes: RAMM 4073–4087. Figured hypotype: USNM 218301.

Discussion.—See *Acteocina canaliculata* (Say, 1826).

Genus **VOLVULELLA** Newton, 1891

Volvulella aspinosa (Dall, 1889)
Plate 15, figures 30, 31

Volvula aspinosa Dall, 1889, pp. 6, 51.
Volvulella paupercula (Watson, 1883). Harry, 1967, p. 133 (not of Watson, 1883, 1886).

Diagnosis.—Shell very small, subcylindrical, evenly tapering. Spire involute, not pointed. Aperture elongate, narrow. Sculpture of obsolete lines on the base and apex of the shell. Columellar fold lacking.

Measurements.—Length, 2.5 mm; body whorl diameter, 5.6 mm.

Distribution.—Pleistocene: Virginia; Recent: North Carolina to Florida and the West Indies.

Occurrence in this study.—Locality 17d.

Type information.—Holotype: USNM 95302. Figured hypotype: USNM 218300.

Discussion.—Harry (1967) placed *V. aspinosa* in synonymy with *V. paupercula.* However, *V. paupercula,* as figured by Watson (1886, pl. 50, fig. 5) is a smaller, more narrow-elongate shell characterized by spiral sculpture over the entire body whorl; whereas *V. aspinosa* (as well described by Abbott, 1974) has strong spiral sculpture at each end, but is smooth in the middle of the whorl. Dall's figure, copied by Abbott (1974, fig. 4029), agrees in outline with our specimen, but shows no spiral sculpture. The species is very rare in the Virginia Pleistocene.

DUBIOUS TAXA

The following taxa have been reported from the Virginia Pleistocene in various papers, but are here considered dubious because of unlikely identifications, probable reworking from Pliocene strata, collection from spoil of uncertain age, or because they were based on specimens now missing or unavailable for study. Some of these taxa may be subsequently validated, and are here listed as an aid to future studies.

Richards (1962, pp. 74–75) lists the following as Virginia records from an otherwise unspecified reference in the pyramidellid literature: *Turbonilla reticulata* (Adams, 1850); *Turbonilla puncta* (Adams, 1850); *Odostomia impressa* (Say, 1822). While *T. puncta* has not been subsequently discovered, it is not an unreasonable record, judging from its Recent range of North Carolina to the Caribbean, and the record is therefore included in the text.

Richards was also the authority for the mollusk identifications that Oaks (1964) listed in his table C-1. Richards (1966, 1967) then provided illustrations for these and other new Virginia Pleistocene records. However, the illustrations were, whenever possible, lifted from Richards (1962), and do not represent Virginia specimens. These records, when subsequently validated or judged to be reasonable, are incorporated into our text, but the following records are judged dubious: *Glycymeris americana* (DeFrance, 1829) [most likely derived from the underlying Pliocene]; *Chione cancellata* (Linné, 1767) [based on beach specimens]; *Hiatella arctica* (Linné, 1767) [Richards (1966) repeats his 1962 illustrations of a small, misidentified *Petricola pholadiformis* Lamarck, 1818, and a *Paramya subovata* (Conrad, 1845)]; *Crepidula aculeata* (Gmelin, 1791) [most likely derived from the underlying Pliocene]; *Vermicularia spirata* (Philippi, 1836) [we have seen no specimens of this distinctive species in undisputed Virginia Pleistocene]; *Vermetus nigricans* (Dall, 1884) [Richards (1967) figures part of an annelid reef]; *Diodora cayenensis* (Lamarck, 1822) [based on beach specimens]; *Laevicardium mortoni* (Conrad, 1831) [based on beach specimens].

Schideler *et al.* (1972) describe both the Quaternary reflector horizons found in the shallow shelf off Virginia Beach, and the sediments and faunas of five vibracores in the area. Student identifications of mollusks were used to develop a biostratigraphy through three horizons called Unit B (Carbon dates >37,000 years); Unit C (Carbon dates of 25,700 and 20,400 years); and Unit D (4200 years, and therefore subfossil). While there is no doubt that the taxonomy was internally consistent and the biostratigraphy valid, some of the identifications are extremely suspect and should not be taken as certain records or range extensions of either Pleistocene or Recent species. For an authoritative report of the Recent faunas of this area, see Franz and Merrill (1980), and Merrill, Bullock, and Franz (1978). The suspect species include: *Adeorbis holmesii* Dall, 1892, *Cyclostremiscus obliquestriatus* (Lea, 1843), and *Ringicula guppyi* Dall, 1889 [Pliocene species]; *Adeorbis supranitidus* Wood, 1848 [European]; *Yoldia lenticula* (Moller, 1842) [a *Portlandia* reported from north of Cape Cod in 110 to 122 fathoms]; *Microgaza rotella* Dall, 1884 [reported off North Carolina but common only in tropical waters in 50 to 100 fathoms]; *Sportella constrata* [no such usage can be found in the literature. *Sportella constricta* (Conrad, 1841), an extinct Pliocene species, may be intended].

APPENDIX

Collecting Localities and Measured Sections

Localities 1, 5, 7–16 and their contained fauna are cited by Richards (1962, p. 48). Their stratigraphic position with respect to the present study is not clear, but they are included in this locality listing because of some similarities in faunal occurrences.

1.—"Near Taft, Lancaster County, North Bank of Rapahannock River Taft and Mosquito Point. 10 foot Bluff."

5.—"Iron Point, Mathews County. A 15- to 20-foot bluff on Godfrey Bay on left bank of Piankatank River, about half a mile south of Iron Point."

7.—"Mumford Island, Gloucester County. On northeast bank of York River, opposite Yorktown. Coquina deposit just above tide."

8.—"Lee's Wharf, Nansemond County. Low bluffs on both sides of Nansemond River at highway eighteen miles below Suffolk. Oyster shells."

9.—"Gaskins Wharf, Nansemond County. About half a mile above previous locality."

10.—"Assateague Island, Accomack County. Beach wash."

11.—"Cape Charles, Northampton County. Hydraulic fill from Chesapeake Bay, half a mile south of town of Cape Charles."

12.—"Near Deep Creek, Norfolk County (now Chesapeake). Dismal Swamp Canal, five and one half miles south of Deep Creek."

13.—"Near Lake Drummond, Norfolk County. Spoil Bank along Feeder Canal about a mile east of Lake Drummond."

15.—"Dismal Swamp."

16.—Not described, but cited in Richards, 1962.

17.—Type section, Acredale Formation, Womack Pit, Bonney's Corner, one-half mile southeast of intersection, Indian River Road and Kempsville Road, Virginia Beach, Virginia. USGS Kempsville, 7.5-min. quadrangle (1964); 36°47′30″N, 76°10′13″W. Pit flooded, inaccessible. Section cited top to bottom. (See Text-fig. 4.)

UNIT AND DESCRIPTION	THICKNESS (M)
Powells Crossroads Formation	
Sand Bridge Member:	
1. Silty clay, brown-gray, unfossiliferous, stiff; gravel and pebbles concentrated near bottom and scattered within unit; wavy laminae and mottling; basal contact sharp and irregular.	1.52
Acredale Formation	
Kempsville Member:	
1. Sandy, light-brown to brown-yellow, fine to medium, cross-bedded; lenses and stringers of peaty clay; some silt; lenses of granules and pebbles near base and scattered lenses throughout; ghosts of *Spisula* and other pelecypod shells in upper portion, disarticulated and oriented convex up. Upper part of Kempsville, nearshore marine; **(Sample 17a)**.	1.37
2. Sand, white to light brown-gray, medium to coarse; becomes coarser downward to coarse sand, granules and pebbles; shell material broken and abraded with some whole specimens; *in situ* burrowing pelecypods near base; iron oxidation layers numerous, concentrated near base to give a pseudo-basal contact that is irregular. Upper part of Kempsville, nearshore marine; **(Sample 17b)**.	0.61
3. Sand, white to brown-yellow, fine to medium, cross-bedded; lenses and stringers of dark gray to black clay; iron oxidation layers scattered throughout with a 7 to 15 cm zone at base which is gradational with next lower unit; ghosts of *Spisula* and other bivalves present, disarticulated, oriented convex up.	1.28
4. Silty sand, light gray to blue-gray, fine to coarse; cross-bedding in upper part, not apparent in lower part; very fossiliferous, mostly disarticulated shell material in upper part grading downward into more whole valves with 15 to 30 cm zone of *Mercenaria* in living position near base; basal contact gradational to sharp toward southwest; *Ophiomorpha* burrows. Lower part of Kempsville, shallow marine; **(Sample 17c)**.	1.25
Norfolk Member:	
1. Silty sand, gray to blue-gray, fine to medium; serpulid worm-tube and bryozoan encrusting bioherm, fossiliferous with *in situ* gastropods and pelecypods. Upper part of Norfolk, open marine; **(Sample 17d)**.	0.73
2. Silty sand, gray to blue-gray, fine to medium; fossiliferous, in place. Upper part of Norfolk, transitional marine; **(Sample 17e)**.	2.29
Great Bridge Member:	
1. Silty sandy clay and clayey to silty sand, fine, dark gray-brown to green-brown; locally fossiliferous, estuarine; **(Sample 17f)**.	0.64
TOTAL EXPOSED	10.55

18.—Type section, Powells Crossroads Formation, Powells Crossroads Pit (Holland Road) one-tenth mile northeast of intersection Kempsville and Holland Roads. (Mount Trashmore), Virginia Beach, Virginia. USGS Kempsville 7.5 min. quadrangle (1965); 36°50′00″N, 76°08′00″W. Pit flooded, inaccessible. Section cited top to bottom. (See Text-fig. 4.)

UNIT AND DESCRIPTION	THICKNESS (M)
Powells Crossroads Formation	
Sand Bridge Member:	
1. Silty clay, brown-gray, unfossiliferous, stiff; granules and pebbles concentrated near bottom and scattered within; basal contact sharp and irregular.	1.10
2. Sand, white to gray-white, fine to medium grained, cross-bedded; clay stringers and lenses and badly weathered shell fragments; iron oxidized layers scattered throughout; grades into next lower unit.	1.43
3. Sand, gray-white to light brown, medium to coarse, cross-bedded; granules and pebbles concentrated at top and base where iron oxidation, fine fossil-hash, and local cementation occur; grades into next lower unit.	0.40
4. Sand, gray, medium to coarse; granules and pebbles; fossiliferous, tightly packed with disarticulated, broken shells and *Spisula*; granule and pebble zone near base grading into coarse sands of next lower unit. Upper part of Sand Bridge, nearshore, shallow marine; **(Sample 18a)**.	0.73
5. Sand, gray, silty grading upward to coarse sand near top; thin lenses of clay near bottom; locally fossil hash near base, otherwise fossiliferous with bay to tidal forms referable to *Ensis, Divalinga,* and *Nucula*; grading upward into fossiliferous gray sands containing a marine shelf fauna; grading upward into coarser sands with lenses of disarticulated and broken shell material containing *Spisula, Donax,* and other nearshore genera. Lower part of Sand Bridge, open marine; **(Sample 18b)**.	0.79
Londonbridge Member:	
1. Clay, dark gray to blue-gray, sandy to silty, grading downward to a silt and silty fine sand;	

sparsely fossiliferous; bottom contact sharp and irregular; estuarine; (**Sample 18c**). 1.16

Acredale Formation

Norfolk Member:

1. Silty sand, light gray to blue-gray, fine to medium, grading downard to clayey sand; very fossiliferous; basal contact gradational to irregular. Upper part of Norfolk, open marine; (**Sample 18d**). 2.44

Great Bridge Member:

1. Silty to sandy clay to clayey sand, dark gray to gray-brown to green-brown; fossiliferous, estuarine; (**Sample 18e**). 0.37

TOTAL EXPOSED 8.41

19.—E. V. Williams Zahyer (Pavab) Pit. One-half mile northwest of intersection of Witchduck Road and Virginia Beach Boulevard, Chinese Corner, Virginia Beach, Virginia. USGS Kempsville 7.5-min. quadrangle (1965); 36°51′25″N, 76°09′27″W. Pit flooded. Section cited top to bottom. (See Text-fig. 4.)

UNIT AND DESCRIPTION — THICKNESS (M)

Powells Crossroads Formation

Sand Bridge Member:

1. Silty clay, brown to brown-gray, unfossiliferous, mottled, laminated, stiff; granules and pebbles concentrated near base and scattered throughout; basal contact sharp and irregular. 1.22

2. Sand, gray-white to tan, fine to medium grained, cross-bedded; some silty sand and clayey sand; clay stringers and lenses; unfossiliferous. 1.62

3. Sand, gray-brown to tan, fine to medium; lenses of clayey sand, sandy clay and clay with small to large lenses of coarse sand, granules and pebbles; lenses sparsely fossiliferous; bottom contact sharp and irregular where clay or pebbles occur, gradational where there is sand. Upper part of Sand Bridge, nearshore marine; (**Sample 19a**). 1.16

4. Sand, white to gray-white to tan, medium to coarse, cross-bedded; fine to medium sand and clayey sand near top; some granules and pebbles near base; basal contact sharp and irregular. 2.65

Acredale Formation

Norfolk Member:

1. Silty sand, gray to blue-gray, fine to medium; fossiliferous. Upper part of Norfolk, open marine. 0.91

TOTAL EXPOSED 7.56

20.—E. V. Williams Ferrel Farm (New Light) Pit, one-half mile west of intersection of Indian River Road and Kempsville Road, Virginia Beach, Virginia. USGS Kempsville 7.5 min. quadrangle (1965); 36°47′45″N, 76°11′00″W. Pit flooded. Section cited from top to bottom. (See Text-fig. 4.)

UNIT AND DESCRIPTION — THICKNESS (M)

Powells Crossroads Formation

Sand Bridge Member:

1. Silty clay, gray to brown-gray, unfossiliferous, mottled, laminated, stiff; granules and pebbles concentrated near bottom and scattered throughout; basal contact sharp and irregular. 0.82

2. Sand, brown to green-brown, medium to coarse; abundant granules and pebbles occurring in an apparent tidal or storm channel cut into underlying Kempsville barrier and beach sands; very fossiliferous with disarticulated, broken and abraded shells; contact irregular and sharp. Lower part of Sand Bridge, shallow marine; (**Sample 20a**). 2.96

Acredale Formation

Kempsville Member:

1. Sand, tan to brown-yellow to light yellow, fine to medium; lenses of granules and pebbles; ghosts of pelecypods, disarticulated and oriented convex up. 0.24

2. Sand, white to brown-yellow, fine to medium, cross-bedded; interbedded with thin to thick beds of dark brown clay and clay lenses; iron oxidation zones present throughout; mottling, ripples, burrows, and ghosts present of various levels.* 2.71

3. Sand, white to brown-yellow, fine, cross-bedded; thin lenses of clay; iron oxidation zones scattered; coarsens toward base to coarse sand, granules and pebbles; basal contact sharp and irregular. 7.74

Norfolk Member:

1. Clayey to silty sand, gray to blue-gray, fine to medium; very fossiliferous with abundant *Mercenaria, Mulinia,* and *Tagelus.* Transitional marine; (**Sample 20b**). 1.10

TOTAL EXPOSED 15.58

21.—Deep Creek Industries Pit, Dowdy Lane (off Old Mill Road) near Yadkin, Deep Creek area of Chesapeake, Virginia. USGS Norfolk South 7.5-min quadrangle (1965); 36°45′30″N, 76°22′00″W. Pit active. Section from NNE pit wall near transmission line tower; cited from top to bottom. See locality 32 also. (See Text-fig. 4.)

UNIT AND DESCRIPTION — THICKNESS (M)

Powells Crossroads Formation

Sand Bridge Member:

1. Silty-clay, gray to gray-brown, unfossiliferous, stiff; wavy laminae, mottled; basal contact sharp and irregular. 0.64

2. Silty to clayey sand, dark brown to yellow-brown, fine to medium, cross-bedded; many clay stringers and lenses and organic material; unfossiliferous; basal contact sharp; in places cut through underlying Norfolk, Great Bridge channel deposit and red-colored Pliocene sediments. 3.14

Acredale Formation

Norfolk Member:

1. Silty to clayey sand, brown to gray-brown to blue-gray, fine to medium; fossiliferous; (**Sample 21a**). 1.65

2. Sand, gray-brown to brown, medium to coarse sand, granules, pebbles and cobbles; shell material broken, worn and abraded; disarticulated *Mercenaria* oriented convex up forming pavement; indurated mudballs and iron concretions with desiccation cracks; basal contact sharp where it is in contact with Pliocene sediments. 0.24

* The above two units are missing where the Sand Bridge channel occurs.

?Great Bridge Member:	
1. Silty clay, dark gray to black, some sandy clay; much mottling of yellow-brown silty clay; much organic material including stems, branches, leaves and seeds; vertebrate remains: tusk of *Mammut* sp.; channel deposit, cuts downward into Pliocene Yorktown.	1.28
Croatan Formation (Pliocene)	
1. Silty to clayey sand, red to dark red-brown, fine to coarse; much broken shell material and disarticulated valves oriented convex up; indurated mudballs, hematite nodules, pebbles and cobbles near base; contact irregular and sharp.	0.85
Yorktown Formation (Pliocene)	
1. Silty sand, brown-green to blue-green; packed with broken and whole shell material; locally well cemented.	3.05
TOTAL EXPOSED	8.96

22.—Toy Avenue Pit (Davis Corner Pit, Shoney's Pit). Between dead end of Toy Avenue (one block south of Virginia Beach Boulevard) and Route 44, Virginia Beach, Virginia. USGS Kempsville 7.5-min. quadrangle (1965); 36°50'30"N, 76°10'20"W. Pit flooded, inaccessible. Section cited top to bottom. (See Text-fig. 4.)

UNIT AND DESCRIPTION	THICKNESS (M)
Powells Crossroads Formation	
Sand Bridge Member:	
1. Silty clay, gray to brown-gray, unfossiliferous, stiff; granules and pebbles concentrated near base and scattered within; wavy laminae and mottling; basal contact sharp and irregular.	1.19
Acredale Formation	
Kempsville Member:	
1. Silty sand, white to light-brown, fine to coarse, cross-bedded; coarsening downward with granules and pebbles concentrated near base and occasionally occurring as thick to thin lenses throughout unit; lenses and stringers of dark brown to black silty clay; iron oxidation layers common.	2.47
2. Sand, gray to light-gray to brown, medium to coarse, cross-bedded; bands of iron oxidation; fossiliferous; granules and pebbles along with much broken and abraded shell material and disarticulated *Mercenaria* and *Spisula* oriented convex up occurring near top and bottom of this unit as well as occurring as beds and lenses within; basal contact sharp. Lower(?) part of Kempsville, shallow nearshore marine; **(Sample 22a)**.	1.65
Norfolk Member:	
1. Silty sand, gray to blue-gray, fine to medium, fossiliferous; thick serpulid bioherm developed and articulated pelecypods in living position.	3.26
2. Silty to clayey sand, brown-gray to gray, fine; basal contact gradational to sharp; fossiliferous, transitional marine; **(Sample 22b)**.	1.31
Great Bridge Member:	
1. Silty to sandy clay, gray to gray-green; some clayey to silty sand; estuarine; **(Sample 22c)**.	0.88
TOTAL EXPOSED	10.76

23.—Owl Creek Marina, one mile south of Rudee Inlet, Virginia Beach, Virginia. USGS Virginia Beach 7.5-min quadrangle (1965); 36°49'30"N, 75°54'47"W. Marina dredged for beach replenishment. Fossils found in dredge dumps on tourist beach near end of 17th Street.

25.—Greenbriar Farm Pit, one-half mile south of Interstate 64, one mile east of I-64, Battlefield Boulevard intersection, Chesapeake, Virginia. USGS Kempsville 7.5-min. quadrangle (1965); 36°47'00"N, 76°13'30"W. Pit flooded, inaccessible. Section cited top to bottom. (See Text-fig. 4.)

UNIT AND DESCRIPTION	THICKNESS (M)
Powells Crossroads Formation	
Sand Bridge Member:	
1. Silty clay, gray to brown-gray, unfossiliferous, stiff; granules and pebbles concentrated near base and scattered throughout; basal contact sharp and irregular.	1.22
Acredale Formation	
Norfolk Member:	
1. Silty sand, gray to light gray, fine to medium; fossiliferous with thin serpulid worm tube bioherm.	0.27
2. Silty sand, gray to light gray, fine to medium; fossiliferous.	0.37
3. Silty sand, gray to light gray, fine to medium; fossiliferous with very large serpulid bioherm developed, most massive in lower three-quarters of this unit; *Mercenaria* and other pelecypods articulated and in life position. Upper part of Norfolk, transitional marine; **(Sample 25a from upper 3 ft)**.	4.51
4. Silty to clayey sand, dark gray, fine; thin clay layer near top; fossiliferous with abundant *Mercenaria* and *Ensis*.	0.79
TOTAL EXPOSED	7.16

26.—Davis Corner North Pit (Lake Edward) 0.4 mi north of intersection of Virginia Beach Boulevard and Newtown Road, 0.2 mi west of Newtown Road, Virginia Beach, Virginia. USGS Kempsville 7.5-min. quadrangle (1965); 36°51'30"N, 76°11'00"W. Pit flooded, inaccessible. (See Text-fig. 4.)

UNIT AND DESCRIPTION	THICKNESS (M)
Powells Crossroads Formation	
Sand Bridge Member:	
1. Silty clay, gray to brown, unfossiliferous, stiff; granules and pebbles concentrated near base and scattered within; basal contact sharp and irregular.	0.52
Acredale Formation	
Kempsville Member:	
1. Silty sand, light brown to gray, fine to medium, cross-bedded; bands of iron oxidation; basal contact gradational.	1.10
Norfolk Member:	
1. Silty sand, gray to blue-gray, fine to medium; fossiliferous with serpulid bioherm developed and articulated pelecypods in place, nearshore, shallow marine; **(Sample 26a)**.	2.32
TOTAL EXPOSED	3.93

27.—Exposure along James River at termination of State Road 1506, Eclipse, Nansemond County, Virginia. USGS Newport News South 7.5-min. quadrangle (1964); 36°55′05″N, 76°00′00″W.

28.—Sample from spoil heap and plastic tube boring. Collected in borrow pit on north side of Norfolk and Western Railroad, 0.4 mi northeast of US 460, Bowers Hill, Chesapeake, Virginia. USGS Bowers Hill 7.5-min. quadrangle (1965); 36°47′07″N, 76°23′27″W.

29.—Core boring just south of house on farm road east of State Highway 10, 0.9 mi northwest of intersection with U. S. Highway 258 at Benns Church, Isle of Wight County, Virginia. Altitude of top of boring is 42.0 ft (Coch, 1968, p. 34). Assigned to the Norfolk Formation, sand facies by Coch (1968).

30.—0.3 mi north of Baileys Beach on Burwells Bay, Isle of Wight County, Virginia. USGS Bacons Castle 7.5-min quadrangle (1969); 37°05′13″N, 76°39′45″W.

32.—Deep Creek Industries Pit, Dowdy Lane (off Old Mill Road) near Yadkin, Deep Creek area of Chesapeake, Virginia. USGS Norfolk South 7.5-min. quadrangle (1965); 36°45′30″N, 76°22′00″W. Pit active. Section from west wall of pit. Section cited from top to bottom. See locality 21 also. (See Text-fig. 4.)

UNIT AND DESCRIPTION	THICKNESS (M)
Acredale Formation	
Norfolk Member:	
1. Silty sand, brown, fine to medium; sparse fauna.	0.40
2. Silty sand, brown, fine to medium; fossiliferous with *Ensis* hash and abundant *Mulinia*; some *Crassostrea, Polinices, Nassarius, Nucula, Anadara transversa, Busycon.*	0.09
3. Silty sand, brown, medium. Sparsely fossiliferous; bioturbation present; grades NW into gray fossiliferous fine to medium clayey sand.	1.22
4. Clayey sand, red to dark brown, iron cemented, fine; shells all convex up; large *Mercenaria,* igneous pebbles to cobbles, quartzite cobbles with *Scolithus,* mud lumps and mudstone balls with desiccation cracks and frequently armored; zone commonly cemented into iron hard pan; basal contact irregular and sharp.	0.30
Croatan Formation (Pliocene)	
1. Sand, medium to coarse, gray-brown to red-brown; coarse shell hash of large bivalves; *Argopecten* thin, imbricated, frequently broken; marine forms include *Argopecten, Pitar, Glycymeris americana, G. subovata, Cyclocardia granulata, Spisula confraga, Anadara plicatura,* large *Noetia.* All are oriented convex up; brackish water forms include abundant *Corbicula,* both single and paired valves, randomly distributed throughout this zone; *Corbicula* much less weathered, some preserving more traces of periostracum than same species occurring lower in this section; also single valves of *Rangia, Tagelus,* and *Crassostrea*; fragments of crab and sand dollars. Paired *Mercenaria* also found elsewhere within this same zone.	1.04
2. Silty sand, brown to red-brown, fine to medium with much friable shell hash; large shells less common but imbricated and convex up; *Glycymeris subovata* very common, convex up; occasional mudball.	0.27
3. Silty sand, red brown to dark red, fine to coarse; shell hash with large shells convex up, commonly mudballs with desiccation cracks and cobbles to pebbles; *Corbicula* present; *Argopecten eboreus* imbricated and convex up. Entire sequence stained and indurated by iron.	0.34
Yorktown Formation (Pliocene)	
1. Sand, brown-gray, fine; broken, friable shell hash; heavily indurated. Occasionally a desiccated mudball occurs near top of this zone; base covered; 200 ft north, this zone contains the indurated shell hash with common *Glycymeris, Cyclocardia, Astarte* and pectens; lacks *Corbicula.*	0.24
TOTAL EXPOSED	5.49

33.—Reference section, Acredale Formation. Gomez Pit, one-third mile north of the intersection of Centerville Turnpike and Kempsville Road (Mears Corner), Virginia Beach, Virginia. USGS Kempsville 7.5-min. quadrangle (1965); 36°47′41″N, 76°10′40″W. Section cited from top to bottom. (See Text-figs. 2 and 3.)

UNIT AND DESCRIPTION	THICKNESS (M)
Powells Crossroads Formation	
Sand Bridge Member:	
1. Silty clay, brown-gray to dark brown, unfossiliferous with laminae and mottling; pebbles scattered throughout; burrowing locally; basal contact sharp and irregular to gradational.	1.52
Acredale Formation	
Kempsville Member:	
1. Sand, light-brown to brown-yellow, fine to medium, cross-bedded with lenses and stringers of peaty clay; lenses of pebbles and gravel near base and scattered throughout; ghosts of *Spisula* and other shells in upper part, mostly disarticulated and oriented convex up, some articulated and in living position.	1.68
2. Sand, white to light brown-gray, medium to coarse, cross-bedded sand; coarsens downward; ghosts of shell material, disarticulated, oriented convex up; ghosts of *in situ* burrowing pelecypods and mud filled burrows; iron oxidation layers numerous, concentrated near base to give a pseudobasal contact which is irregular.	2.74
3. Sand, gray, fine; very fossiliferous, burrowed, two rows of *Mercenaria* in life position separated by serpulid worm tubes with encrusting bryozoans. Grades into next lower unit.	1.52
Norfolk Member:	
1. Sand, gray to blue-gray, fine; mostly leached; grading downward into silty and clayey sand and silty clay; leached areas with abundant shell ghosts; much channeling, containing coarser sand and shell debris; abundant *M. mercenaria* and *C. virginica* occurring in 0.6 m bed near base; basal contact sharp commonly overlying single discontinuous layer of scattered cobbles and boulders; elsewhere contact more gradational with dark gray to black silty sand to silty clay overlying dark gray clay.	2.43
Great Bridge Member:	
1. Silty sand to clay, light gray to brown, fine	

grained; clay, blue-gray to dark gray to black; burrowed; some channels and lenses of medium to coarse sand to gravel occasionally; sparsely fossiliferous. 3.05

2. Tree stump layer; *in situ* tree stumps of cypress, sweet gum, pine and oak frequently encased in bluish-gray clay that is sparsely fossiliferous; occasionally encased in white to tan silty sand; roots extend downward into underlying boulder layers. 0.3

3. Boulder layer consisting of single layer of cobbles to boulders; clasts consisting of greenstones, quartzites, gneisses and schists; unconformably overlies fine to medium sand to clay, the depth and age of which is unknown. 0.3

TOTAL EXPOSED 13.54

REFERENCES CITED

Abbott, M. L. B.

1971. [MS] *Systematics and ecology of populations of* Hippoporina neviana (*Bryozoa-Cheilostomata*) *from Block Island Sound, New York: a study in intercolony variation.* Ph.D. Dissertation, University of Connecticut, 166 pp.

1975. *Relationship of temperature to patterns of sexual reproduction in some Recent encrusting Cheilostomata,* pp. 37–50, *in* Pouyet, S. (ed.), *Bryozoa 1974, Proceedings of the Third Conference International Bryozoology Association.* Doc. Lab. Geologie, Fac. Sci. Lyon, hors. serv. 3, fasc. 1, pp. 1–256.

Abbott, R. T.

1954. *American seashells.* Van Nostrand, New York, 541 pp.

1957. Prunum roscidum *in New Jersey.* Nautilus, vol. 71, No. 2, pp. 52–53.

1968. *A guide to field identification: Seashells of North America.* Golden Press, New York. 280 pp.

1974. *American seashells.* 2nd Ed., Van Nostrand Reinhold Co., New York, 663 pp.

Abbott, R. T., and Jensen, R. H.

1967. *Molluscan faunal changes around Bermuda.* Science, vol. 155, No. 3763, pp. 687–688.

Adams, C. B.

1839. *Observations on some species of the marine shells of Massachusetts, with descriptions of five new species.* Boston J. Nat. Hist., vol. 2, pp. 262–288.

1840. *Observations of thirteen new species of New England shells.* Boston J. Nat. Hist., vol. 3, pp. 318–332.

1845. *Specierum Novarum Conchyliorum in Jamaica Repertorum, Synopsis.* Boston Soc. Nat. Hist., Proc., vol. 2, pp. 1–17.

1850. *Descriptions of supposed new species of marine shells which inhabit Jamaica.* Contrib. Conch., No. 4, pp. 56–58; No. 5, pp. 69–75.

1852. *Descriptions of new species of* Corbula *from Jamaica.* Contrib. Conch. No. 12, pp. 233–241.

Adams, H.

1861. *Descriptions of some new genera and species of shells from the collection of Hugh Cuming, Esq.* Geol. Soc. London, Proc. for 1861, pp. 383–385.

Adams, H., and Adams, A.

1853–58. *The genera of Recent Mollusca; arranged according to their organization.* London, John Van Voorst, 2 vols. of text, 1 vol. of plates; vol. 1, 484 pp., vol. 2, 681 pp., vol. 3, 136 pls.

Allison, R. C.

1973. *Marine paleoclimatology and paleoecology of a Pleistocene fauna from Amchitka Island, Aleutian Islands, Alaska.* Palaeogeog., Paleoclimat., Palaeoecol., vol. 13, pp. 15–48.

Andrews, J.

1971. *Sea shells of the Texas coast.* Univ. of Texas Press, Austin. xv + 298 pp.

1977. *Shells and shores of Texas.* Univ. of Texas Press, Austin, 365 pp.

Angas, G. F.

1877. *Description of one genus* [Mysella] *and twenty-five species of marine shells from New South Wales.* Zool. Soc. London, Proc. for 1877, pp. 171–177, pl. 26.

Audovun, J. V.

1826. *Explication sommaire des Planches de Polypes de l'Egypte et de la Syrie* in *Description de l'Egypte, Hist. Nat.,* vol. 1, pt. 4, pp. 225–249.

Balsam, W. L., and Heusser, L. E.

1976. *Direct correlation of sea surface paleotemperatures, deep circulation and terrestrial paleoclimates; foraminiferal and palynological evidence from two cores off Chesapeake Bay.* Mar. Geol., vol. 21, No. 2, pp. 121–147.

Bartsch, P.

1916. Eulimastoma: *a new subgenus of pyramidellids and remarks on the genus* Scalenostoma. Nautilus, vol., 30, No. 7, pp. 73–74.

1917. *A monograph of West American melanellid mollusks.* U. S. Nat. Mus., Proc., vol. 53, No. 2207, pp. 295–356, pls. 34–49.

1920. *The Caecidae and other marine molluscs from the northwest coast of America.* Washington Acad. Sci., J., vol. 10, No. 20, pp. 565–572.

Bassler, R. S.

1935. *Bryozoa* [in] Quenstedt, Werner, ed., *Fossilium Catalogus. 1. Animalia. pt. 67.* The Hague, W. Junk, 229 pp.

1936. *Nomenclatorial notes on fossil and Recent Bryozoa.* Washington Acad. Sci., J., vol. 26, pp. 156–162.

Beauperthuy, I.

1967. *Los mitilidos de Venezuela (Mollusca: Bivalvia).* Bol. Inst. Oceanogr. Cumana, vol. 6, No. 1, pp. 7–114.

Belknap, D. F., and Wehmiller, J. F.

1980. *Amino acid racemization in Quaternary molluscs: Examples from Delaware, Maryland, and Virginia, in* Hare, P. E. (ed.), *Biogeochemistry of amino acids.* John Wiley and Sons, New York, pp. 401–414.

Bequaret, J. C.

1943. *The genus* Littorina *in the Western Atlantic.* Johnsonia, vol. 1, No. 7, pp. 1–27.

Berry, S. S.

1910. [Review of]*Report on a collection of shells from Peru, with a summary of the littoral marine Mollusca of the Peruvian Zoological Province,* by W. H. Dall. Proceedings of the United States National Museum, vol. 37 (pp. 147–249, 1901. Nautilus vol. 23), No. 10, pp. 130–132.

Blainville, H. M. Ducrotay de

1814–1830. *Vers et Zoophytes, in* George F. Cuvier, *Dictionnaire des sciences naturelles. Pt. 2, Regne organise.* Paris. vols. 60, pp. 1–546, pls. 67–78 in Atlas.

Blake, C. H.

1933. *Order Ostracoda, in* Proctor, W. (ed.), *Crustacea, biological survey of the Mount Desert region.* Wistar Inst. Press, pp. 229–241.

Blake, S. F.

1953. *The Pleistocene fauna of Wailes Bluff and Langley Bluff,* *Maryland.* Smithsonian Misc. Coll., vol. 121, No. 12, pp. 1–32.

Bolten, J. F.

1798. *Museum Boltenianum . . . pars secunda continens Conchylia sive Testacea univalvia, bivalvia et multivalvia.* Hamburg, viii + 199 pp.

Born, I.

1780. *Testacea Musei Caesarei Vindobonensis.* Vienna, xxxvi + 442 pp. + Appendix, 17 pp.

Boss, K. J.

1968. *The subfamily Tellinidae in the Western Atlantic; The genera* Tellina *(Part II) and* Tellidora. Johnsonia, vol. 4, No. 46, pp. 273–344.

Boss, K. J., and Merrill, A. S.

1965. *The family Pandoridae in the Western Atlantic.* Johnsonia, vol. 4, No. 44, pp. 181–215.

Bousfield, E. L.

1961. *Noteworthy records of marine molluscs from the Bay of Fundy.* Nat. Mus. Canada, Natural History Papers, No. 10, pp. 1–3.

Bowdich, T. E.

1822. *Elements of Conchology, including the fossil genera and animals.* Paris and London, 119 pp.

Brady, G. S.

1870. *Recent ostracoda from the Gulf of St. Lawrence.* Annals and Mag. Nat. History, 4th ser., vol. 6, pp. 450–454.

Bretsky, P. W.

1968. *Evolution of Paleozoic marine invertebrate communities.* Science, vol. 159, pp. 1231–1233.

Bronn, H. G.

1831. *Italiens Tertiär-Gebilde und deren organische Einschlusse.* Heidelberg, viii + 176 pp., 4 pls.

Brown, A. P., and Pilsbry, H. A.

1913. *Two collections of Pleistocene fossils from the Isthmus of Panama.* Acad. Nat. Sci. Philadelphia, Proc., vol. 65, pp. 493–500.

Brown, T.

1816. *The Elements of Conchology; or natural history of shells; according to the Linnean System.* London. pp. [ix], 168, 9 pls.

1827. *Illustrations of the Conchology of Great Britain and Ireland.** Smith, Elder, & Co., London. 130 pp., 53 pls.

Bruguière, J. G.

1789–1797. *In* Bruguière, J. G., Lamarck, J. B. P., and Deshayes, G. P., 1789–1832, *Encyclopédie Méthodique. Illustoire naturelle des Vers.* vols. 1–3, text and plates. Text, vol. 1, pt. 1, pp. 1–344, 1789; pt. 2, pp. 345–758, 1792; vol. 2, pt. 1, pp. 1–256, 1830; pt. 2, pp. 257–594, 1832; vol. 3, pp. 595–1152. Plates, vol. 1, i–viii + 479 pp., pls. 1–92, 1791; vol. 2, pls. 93–286, 1797; vol. 3, pls. 287–488.

Bush, K. J.

1897. *Revision of the marine gastropods referred to* Cyclostrema, Adeorbis, Vitrinella, *and related genera; with descriptions of some new genera and species belonging to the Atlantic fauna of America.* Connecticut Acad. Arts and Sci., Trans., vol. 10, art. 3, pp. 97–144, pls. 22–23.

1909. *Notes on the family Pyramidellidae.* Am. J. Sci., vol. 27, pp. 475–484.

Busk, G.

1852. *Catalog of the marine Polyzoa in the British Museum. Pt. 1. Cheilostomata.* London, pp. 1–54.

* "Recent" was incorporated into the title with the 2nd edition of 1844.

1854. *Catalogue of the marine Polyzoa in the collection of the British Museum. Cheilostomata, pt. 2,* pp. 55–120.

1859. *Zoophytology. On some Madeiran Polyzoa collected by J. Yates Johnson. Esq.* Microsc. Sci., Q. J., vol. 7, pp. 65–67.

1861. *Zoophytology. Descriptions of new or imperfectly known Polyzoa.* Microsc. Sci., Q. J., n.s., vol. 1, pp. 153–156.

Campbell, S.

1976. [MS] *Holocene and Pliocene molluscan biogeography of the western North Atlantic.* M.S. thesis. Univ. of South Carolina.

Campbell, L., Campbell., S. Colquhoun, D., Ernissee, J., and Abbott, W.

1975. *Plio-Pleistocene faunas of the central Carolina Coastal Plain.* South Carolina Division of Geology, Geologic Notes, vol. 19, pp. 51–124.

Cantraine, F. J.

1835. *Diagnoses ou descriptions succintes des quelques espèces nouvelles de mollusques qui feront partie de l'ouvrage: Malacologie méditerranée et litorale.* Bull. Acad. Roy. Soc. Belles Lettres, Bruxelles, vol. 2, pp. 376–406.

Canu, F., and Bassler, R. S.

1917. *A synopsis of American early Tertiary Bryozoa.* U. S. Nat. Mus., Bull. 96, pp. 1–87.

1919. *Fossil Bryozoa from the West Indies. In* Vaughan, T. W., *Contribution to the geology and paleontology of the West Indies.* Carnegie Inst., Washington, Pub. 291, pp. 73–102, 7 pls.

1923. *North American later Tertiary and Quaternary Bryozoa.* U. S. Nat. Mus., Bull. 125, pp. 1–302.

1925. *Les Bryozoaires du Maroc et de Mauritanie.* Soc. Sci. Nat. Maroc, Mem., No. 10, pp. 1–80.

1927. *Classification of the Cheilostomatous Bryozoa.* U. S. Nat. Mus., Proc. 69, art. 14, pp. 1–42.

1928. *Fossil and Recent Bryozoa of the Gulf of Mexico region.* U. S. Nat. Mus., Proc. 72, art. 14, pp. 1–199.

Castagna, M., and Chanley, P.

1973. *Salinity tolerance of some marine bivalves from inshore and estuarine environments in Virginia waters on the western Mid-Atlantic coast.* Malacologie, vol. 12, pp. 47–96.

Cerame-Vivas, M. J., and Gray, I. E.

1966. *The distributional pattern of benthic invertebrates of the Continental Shelf off North Carolina.* Ecology, vol. 47, No. 2, pp. 260–270.

Charlesworth, E.

1837. *Notice of a new fossil shell from the coast of Suffolk.* The Magazine of Natural History and Journal of Zoology, Botany, Mineralogy, Geology, and Meteorology. Art. 12, vol. 1, n.s., pp. 218–220.

Chavan, A.

1951. *Essai critique de classifications des* Divaricella. Inst. Roy. Sci. nat. Belgique Bull., vol. 27, No. 13, pp. 1–27, 27 figs. in text.

Cheetham, A. H., and Deboo, P. B.

1973. *A numerical index for biostratigraphic zonation in the mid-Tertiary of the eastern Gulf.* Gulf Coast Assoc. Geol. Soc., Trans., vol. 13, pp. 139–147.

Cheetham, A. H., and Hazel, J. E.

1969. *Binary (presence-absence) similarity coefficients.* J. Paleontol., vol. 43, p. 1130–1136.

Cheetham, A. H., and Sandberg, P. A.

1964. *Quaternary Bryozoa from Louisiana mudlumps.* J. Paleontol., vol. 38, No. 6, pp. 1013–1046.

Clapp, W. F.

1914. *A new fossil* Vitrinella *from Boston, Massachusetts.* Nautilus, vol. 28, No. 4, pp. 38–40.

Clark, W.

1855. *A History of the British Marine Testaceous Mollusca Distributed in their Natural Order, on the Basis of the Organization of the Animals; with References and Notes on Every British Species.* London, John van Voorst, 536 pp.

Clark, W. B., and Miller, B. L.

1906. *A brief summary of the geology of the Virginia Coastal Plain. In* Ries, H., *The clay deposits of the Virginia Coastal Plain.* Virginia Geol. Surv., Geol. Series, Bull., vol. 2, pp. 11–24.

1912. *The physiography and geology of the Coastal Plain Province of Virginia.* Virginia Geol. Surv. Bull., vol. 4, pp. 13–222.

Clarke, A. H., Grant, D. R., and MacPherson, E.

1972. *The relationship of* Atractodon stonei *(Pilsbry) (Mollusca Buccinidae) to the Pleistocene stratigraphy and paleoecology of Southwestern Nova Scotia.* Canadian J. Earth Sci., vol. 9, No. 8, pp. 1030–1038.

Clench, W. J.

1947. *The genera* Purpurea *and* Thais *in the Western Atlantic.* Johnsonia, vol. 2, No. 23, pp. 61–91.

Clench, W. J., and Smith, L. C.

1944. *The Family Cardiidae in the Western Atlantic.* Johnsonia, vol. 1, No. 13, pp. 1–32.

Clench, W. J., and Turner, R.

1952. *The genus* Epitonium *in the Western Atlantic, (Part II).* Johnsonia, vol. 2, No. 30–31, pp. 221–356.

Coan, E., and Roth, B.

1966. *The Western American Marginellidae.* The Veliger, vol. 8, No. 4, pp. 276–299.

1971. *Family Marginellidae. In* Keen, A. M., *Sea shells of tropical West America.* 2nd ed., Stanford Univ. Press, Stanford, pp. 632–638.

Coch, N. K.

1965. *Post-Miocene stratigraphy and morphology, Outer Coastal Plain, Southeastern Virginia.* U. S. Office of Naval Research, Geography Branch, Tech. Rept. 5, Task Order N. R. 388–064, 97 pp. (Yale University Ph.D. dissertation).

1968. *Geology of the Benns Church, Smithfield Windsor, and Chuckatuck quadrangles, Virginia.* Virginia Div. Min. Resources, Rept. Inv. 17, 39 pp.

Colquhoun, D. J.

1969. *Terrace sediment complexes in the Carolinas and Georgia. In* Quaternary Geology and Climate. Internat. Assoc. Quat. Res., Proc. 7th Congr. (U. S. Natl. Acad. Sci., Washington, DC), vol. 16, pp. 150–162.

1971. *Glacio-eustatic sea level fluctuation of the Middle and Lower Coastal Plain, South Carolina.* Quaternaria, vol. 15, pp. 19–34.

1974. *Cyclic surficial stratigraphic units of the Middle and Lower Coastal Plains, central and southern Atlantic Coastal Plain.* Utah State Univ. Press, Logan, pp. 179–190.

Colquhoun, D. J., Herrick, S. M., and Richards, H. G.

1968. *A fossil assemblage from the Wicomico Formation in Berkeley County, South Carolina.* Geol. Soc. Amer. Bull., vol. 79, pp. 1211–1220.

Conrad, T. A.

1831. *Description of fifteen new species of Recent and three of fossil shells chiefly from the coast of the United States.* Acad. Nat. Sci. Phila., J., vol. 6, pp. 256–269.

1831–1832a. *American marine conchology, or descriptions and coloured figures of the shells of the Atlantic coast of North America.* 72 pp.

1832b. *Fossil shells of the Tertiary formations of North America, illustrated by figures drawn on stone from nature.* Philadelphia, vol. 1, pts. 1–4, 121 pp., 20 pls. Republished by G. D. Harris, Washington, DC, 1893.

1833. *On some new fossil and recent shells of the United States.* Acad. Nat. Sci. Philadelphia, J., vol. 23, pp. 339–346.

1834. *Descriptions of new Tertiary fossils from the southern states.* Acad. Nat. Sci. Philadelphia, J., vol. 7, No. 133, pp. 130–157.

1835. *Observations on the Tertiary strata of the Atlantic coast.* Am. J. Sci., vol. 28, pp. 104–111, 280–282.

1837. *Descriptions of new marine shells from Upper California, collected by Thomas Nuttall, Esq.* Acad. Nat. Sci. Phila., J. 1st ser., vol. 7, No. 2, pp. 227–268.

1838. *Fossils of the Tertiary formations of the United States.* Phila., No. 1, 136 pp.

1839. *Description of twenty-four new species of fossil shells, chiefly from the Tertiary deposits at Calvert Cliffs, Maryland.* Acad. Nat. Sci. Philadelphia, J., 1st ser., vol. 8, pp. 183–190.

1840. *New fossil shells from North Carolina.* Am. J. Sci., 1st. ser., vol. 39, pp. 387–388.

1841. *Appendix to Mr. Hodge's paper describing the new shells, etc. In* Hodge, J. T., *Observations on the Secondary and Tertiary formations of the southern Atlantic states.* Am. J. Sci., 1st ser., vol. 41, No. 2, pp. 344–348.

1842. *Observations on a portion of the Atlantic Tertiary region, with a description of new species of organic remains.* Proc. Nat. Inst. Bull., vol. 2, p. 194, pl. 1, fig. 2.

1844. *Descriptions of nineteen species of Tertiary fossils of Virginia and North Carolina.* Acad. Nat. Sci. Phila., Proc., vol. 1, pp. 323–329.

1845. *Fossils of the medial Tertiary of the United States.* No. 3, pp. 57–80.

1846. *Descriptions of new species of fossil and Recent shells and corals.* Acad. Nat. Sci. Phila., Proc., vol. 3, No. 1, pp. 19–27.

1849. *Descriptions of new fossil and Recent shells of the United States.* Acad. Nat. Sci. Phila., Proc., vol. 7, pp. 265–268.

1860. *Notes on shells.* Acad. Nat. Sci. Phila., Proc., pp. 231–232.

1862. *Catalogue of the Miocene shells of the Atlantic slope.* Acad. Nat. Sci. Phila., Proc., vol. 14, pp. 559–582.

1862. *Descriptions of new genera, subgenera, and species of Tertiary and Recent shells.* Acad. Nat. Sci. Phila., Proc., vol. 14, pp. 284–291.

1863. *Descriptions of new, Recent and Miocene shells.* Acad. Nat. Sci. Phila., Proc. for 1862, pp. 583–585.

1865. *Catalogue of the Eocene and Oligocene Testacea of the United States.* Am. J. Conchol., vol. 1, pp. 1–35.

1866. *Descriptions of new species of Tertiary, Cretaceous, and Recent shells.* Am. J. Conchol., vol. 2, 106 pp.

1867. *Descriptions of new genera and species of Miocene shells with notes on other fossils and Recent species.* Am. J. Conchol., vol. 3, 267 pp.

1875. *Descriptions of new genera and species of fossil shells of North Carolina. In* Kerr, W. C., *Report of the geological survey of North Carolina.* Raleigh. App., pp. 1–28.

Cook, P. L.

1964. *Polyzoa from West Africa. Notes on the genera* Hippoporina *Neviani,* Hippoporella *Canu,* Cleidochasma *Harmer, and* Hippoporidra *Canu and Bassler (Cleidochasma, Ascophora).* Brit. Mus. (Nat. Hist.) Zool. Bull. 12, No. 1, pp. 1–35.

1965a. *Notes on the Cupuladriidae (Polyzoa, Anasca).* Brit. Mus. (Nat. Hist.) Zool. Bull. 13, No. 5, pp. 153–187.

1965b. *Polyzoa from West Africa, the Cupuladriidae (Cheilostomata, Anasca).* Brit. Mus. (Nat. Hist.) Zool. Bull. 13, No. 6, pp. 191–227.

1968a. *Polyzoa from West Africa; the Malacostega; Part I.* Brit. Mus. (Nat. Hist.) Zool. Bull. 16, No. 3, pp. 115–166.

1968b. *Bryozoa (Polyzoa) from the coast of tropical West Africa.* Alantide Rept. No. 10, pp. 115–262.

Cooke, C. W.

1945. *Geology of Florida.* Florida Geol. Surv. Bull. 29, 339 pp.

Coomans, H. E.

1962. *The marine mollusc fauna of the Virginia area as a basis for defining zoogeographical provinces.* Beaufortia 9, No. 98, pp. 83–104.

Cossman, M.

1899–1925. *Essais de Paléoconchologie comparée.* Paris, 13 parts.

Costa, E. M. da

1776. *Historia naturalis testaceorum Britanniae, or the British Conchology; containing the descriptions and other particulars of natural history of the shells of Great Britain and Ireland: Illustrated with figures.* London, 254 pp., 17 pls.

Cronin, T. M.

1979. *Late Pleistocene marginal marine ostracodes from the southeastern Atlantic Coastal Plain and their paleoenvironmental implications.* Geogr. Phys. Quat., vol. 33, No. 2, pp. 121–173.

1980. *Biostratigraphic correlation of Pleistocene marine deposits and sea levels, Atlantic Coastal Plain of the southeastern United States.* Quat. Res., vol. 13, pp. 213–219.

1981. *Rates and possible causes of neotectonic vertical crustal movements of the emerged southeastern United States Atlantic Coastal Plain.* Geol. Soc. Am., Bull. Part I, vol. 11, No. 92, pp. 812–831.

Cronin, T. M., and Hazel, J. E.

1979. *Ostracode biostratigraphy of Pliocene and Pleistocene deposits of the Cape Fear Arch region, North and South Carolina.* U. S. Geol. Surv. Prof. Paper. 1125-B, pp. 1–25.

Cronin, T. M., Szabo, B. J., Ager, T. A., Hazel, J. E., and Owens, J. P.

1981. *Quaternary climates and sea levels of the U. S. Atlantic Coastal Plain.* Science, vol. 211, pp. 233–240.

Cushman, J. A.

1922. *Results of the Hudson Bay expedition (1920).* Contrib. Canadian Biol., vol. 9, pp. 135–147.

1923. *The Foraminifera of the Atlantic Ocean. Pt. 4. Lagenidae.* U. S. Nat. Mus. Bull. 104, 228 pp.

1930. *The Foraminifera of the Atlantic Ocean. Pt. 7. Nonionidae, Camerinidae, Peneroplidae, and Alveolinellidae.* U. S. Nat. Mus. Bull. 104, 79 pp.

Dall, W. H.

1871. *Descriptions of sixty new forms of mollusks from the west coast of North America and the North Pacific Ocean, with notes on others already described.* Am. J. Conchol., vol. 7, pt. 2, No. 5, pp. 93–160, pls. 13–16.

1884. *On a collection of shells sent from Florida by Mr. Henry Hemphill.* U. S. Nat. Mus., Proc., vol. 6, No. 384, pp. 318–342, pl. 10.

1886. *Report on the results of dredging . . . in the Gulf of Mexico (1877–1878) and in the Caribbean . . . .* Mus. Comp. Zool., Bull., vol. 12, No. 6, pp. 171–318.

1889. *A preliminary catalog of the shell-bearing marine mollusks and brachiopods of the southeastern coast of the United States, with illustrations of many of the species.* U. S. Nat. Mus., Bull. 37, 212 pp.

1890–1903. *Contributions to the Tertiary fauna of Florida; with special reference to the Miocene silex-beds of Tampa and the Pliocene beds of the Caloosahatchie River.* Wagner Free Inst. Sci., Trans., vol. 3, pts. 1–6, 1654 pp., 60 pls.

1894. *Notes on the Miocene and Pliocene of Gay Head, Martha's Vineyard Massachusetts, and on the "land phosphate" of the Ashley River District, South Carolina.* Am. J. Sci., 3d ser. vol. 48(286) art. 42, pp. 296–301.

1897. *Notes on the Paleontological publications of Professor William Wagner.* Wagner Free Inst. Sci., Phila., Trans., vol. 5, pp. 7–11, pls. 1–3.

1900. *Synopsis of the family Tellinidae and of the North American species.* U. S. Nat. Mus., Proc. 23, pp. 285–326.

1901. *Synopsis of the Lucinacea and of the North American species.* U. S. Nat. Mus., Proc., vol. 23, No. 1237, pp. 779–833.

1918. *Changes in and additions to molluscan nomenclature.* Biol. Soc. Washington, Proc., vol. 31, pp. 127–138.

De France, M.

1829. *In* Levrault, F. G. (ed.), *Dict. Science Nat.* Paris Perroq-Phoq, vol. 39, 225 pp.

Dekay, J. E.

1843. *Zoology of New York, or the New York Fauna Pt. 1, Zoology, [sub]pt. 5. Mollusca.* Albany, NY. viii + 271 pp., 40 pls.

Deshayes, P. G.

1830. *Histoire naturelle de vers.* Vol. 2. Encylopédie méthodique. Paris. 196 vols., 1782–1832.

1850. *In* 1839–1857, *Traité élémentaire de Conchyliologie avec les applications de cette science à la Géologie.* Paris.

1853. *Catalogue of the Conchifera or bivalve shells in the British Museum.* London, pt. 1, *Veneridae, Cyprinidae and Glauconomidae,* pp. 1–216, 1853; pt. 2, *Petricoladae* (concluded), *Corbiculadae,* pp. 217–292, 1855.

Deslongchamps, E.

1842. *Mémoire sur les* Trochotoma, *nouveau genre de coquilles fossiles, voisin des Pleurotomaires.* Mem. Soc. linn. Normandie, vol. 7, pp. 100–110.

Desmoulins, C.

1832. *Description d'une nouveau genre de coquille vivante bivalve des mers du Chili.* Soc. Linnéenne Bordeaux, Actes, vol. 5, pp. 83–92.

Desor, E.

1848. *Ascidian polyps, or Bryozoa from Nantucket.* Boston Soc. Nat. Hist., Proc., vol. 3, pp. 66–67.

Dillwyn, L. W.

1817. *A descriptive catalogue of Recent shells.* London. Vols. 1–2, No. 12, 1092 pp., index.

DuBar, J. R.

1959. *Stratigraphy and paleontology of the late Neogene strata of the Caloosahatchee River area of Southern Florida.* Fla. Geol. Surv. Bull., vol. 40, 267 pp.

1971. *Neogene stratigraphy of the Lower Coastal Plain of the Carolinas.* Atlantic Coastal Plain Geol. Assn., 12th Ann. Field Conf. Guidebook, 128 pp.

DuBar, J. R., Solliday, J. R., and Howard, J. F.

1974. *Stratigraphy and morphology of Neogene deposits, Neuse River Estuary, North Carolina. In* Oaks, R. Q., Jr., and DuBar, J. R. (eds.), *Post-Miocene stratigraphy, central and southern Atlantic Coastal Plain.* Utah State Univ. Press, Logan, pp. 102–122.

Dumeril, A. M. C.

1806. *Zoologie analytique ou methode naturelle de classification des animaux.* Paris, 344 pp.

Durham, J. W., and MacNeil, F. S.

1967. *In* Hopkins, D. M. (ed.), *Cenozoic migrations of marine invertebrates through the Bering Strait Region. The Bering Land Bridge.* Stanford Univ. Press, Stanford, pp. 326–349.

Ehrenberg, C. G.
1831. *Symbolae physicae seu icones et descriptiones mammalium avium, insectorum, et animalium evertebratorium.* Paris Zoologica, Berlin, 4 vols.

Emiliani, C.
1955. *Pleistocene temperatures.* J. Geol., vol. 63, pp. 538–578.

Emmons, E.
1858. *Report on the North Carolina Geological Survey. Agriculture of the eastern counties.* Raleigh, xvi + 314 pp.

Esper, E. J. C.
1794–1797. *Forsetzungen der Pflanzenthiere in Abbildungen nach der natur mit Farbenerleuchtet nebst Beschreibungen, Pt. 1.* Theil, 1: pp. 1–230* Nurnberg.

Fargo, W. G.
1953. *The Pliocene Turridae of Saint Petersburg, Florida. Part III.* In Olsson, A. A., and Harbison, A., *Pliocene Mollusca of Southern Florida.* Acad. Nat. Sci. Phila., Monogr. 83, pp. 365–409.

Férussac, A. E.
1820–1822. *Tableaux systématique des animaux mollusques classes en familles naturelles, dans lesquels on a établi la concordance de tous les systèmes; suivis d'un prodrome générale pour tous les mollusques terrestres ou fluviatiles, vivants ou fossiles.* Paris, xiii + 110 pp.

Fischer, P.
1857. *Études sur un groupe de coquilles de la famille des Trochidae.* J. Conchyl., vol. 2, pp. 42–53, 168–176, 284–288.
1887. *Manuel de conchyliogie et de paléontologie conchyliologique.* Paris, xxiv + 1379 pp.

Fischer, P., and Bernardi, M.
1856. *Descriptions d'espèces nouvelles.* J. Conchyl., vol. 5, pp. 357–358.

Fisher, W. K.
1947. *New genera and species of euchiuroid and sipunculoid worms.* U. S. Nat. Museum, Proc., vol. 97, No. 3218, pp. 351–372, pls. 8–15.

Fisher, W. L.
1964. *Sedimentary patterns in Eocene cyclic deposits, northern Gulf Coast region.* Vol. 1, pp. 151–170. *In* Merriam, D. F. (ed.), *Symposium on cyclic sedimentation.* Kansas Geol. Surv. Bull. 169, vols. 1–2.

Fleming, J.
1813. *Conchology.* In *Edinburgh Encyclopedia,* edition 7, vol. 12, pp. 55–107.
1820. *New Edinburgh Encylopedia.* American edition, vol. 13, p. 2.
1822. *Philosophy of Zoology.* vol. 2, Edinburgh, 618 pp., 5 pls.
1825. *On the British testaceous annelides.* Edinburgh philos. J., vol. 12, pp. 238–248.
1828. *A history of British Animals, exhibiting the descriptive characters and systematical arrangement of the genera and species of quadrupeds, birds, reptiles, fishes, mollusca, and radiata of the United Kingdom; including the indigenous, extirpated, and extinct kinds, together with periodical and occasional visitants.* Bell & Bradfute, Edinburgh. xxiii + 565 pp.

Forbes, E., and Hanley, S.
1848. *A History of British Mollusca and their shells, Vol. 1, Lamellibranchs.* London, John Van Voorst. xxx + 477 pp., pls. A–O, 1–34.

Franz, D. R., and Merrill, A. S.
1980. *Molluscan Distribution Patterns on the continental shelf of the Middle Atlantic Bight (Northwest Atlantic).* Malacologia, vol. 9, No. 2, pp. 209–225.

* Pp. 117–168 were published in 1796.

Gabb, W.
1873. *Description of some new genera of Mollusca.* Acad. Nat. Sci. Philadelphia, Proc., vol. 24, pp. 270–274, pls. 9–11.
1881. *Descriptions of new species of fossils from the Pliocene clay beds between Limon and Moen, Costa Rica, together with notes on previously-known species from there and elsewhere in the Caribbean area.* Acad. Nat. Sci. Phila., J., 2nd ser., vol. 8, pp. 349–380.

Gabb, W., and Horn, G. H.
1862. *Monograph of the fossil Polyzoa of the Secondary and Tertiary formations of North America.* Acad. Nat. Sci. Phila., J., new ser., vol. 5, pp. 111–179.

Gardner, J. A.
1943. *Mollusca from the Miocene and lower Pliocene of Virginia and North Carolina, Pt. 1, Pelecypoda.* U. S. Geol. Surv. Prof. Paper 199A, 178 pp.
1948. *Mollusca from the Miocene and lower Pliocene of Virginia and North Carolina, Pt. 2, Scaphopoda and Gastropoda.* U. S. Geol. Surv. Prof. Paper 199B, pp. 179–310.

Gardner, J. A., and Aldrich, T. H.
1919. *Mollusca from the Upper Miocene of South Carolina with descriptions of new species.* Acad. Nat. Sciences, Phila., Proc., vol. 71, pp. 17–53.

Gill, T.
1867. *On the genus* Fulgur *and its allies.* Am. J. Conchol., vol. 3, No. 2, pp. 141–152, 1 fig.

Gmelin, J. F.
1790. *Syst. Nat.* 13th ed., vol. 1, p. 3312.
1791. *Syst. Nat.* 13th ed., vol. 5, p. 3336.

Gould, A. A.
1841. *Report on the Invertebrata of Massachusetts, comprising the Mollusca, Crustacea, Annelida, and Radiata.* Cambridge. 373 pp.
1851. *Descriptions of a number of California shells collected by Maj. William Rich and Lieut. Thomas P. Green, United States Navy.* Boston Soc. Nat. Hist. Proc., vol. 4, pp. 87–93.
1862. *Otia Conchologica: descriptions of shells and mollusks from 1839 to 1862.* Boston. 256 pp.

Gray, J. E.
1824. *Shells.* In *A Supplement to the Appendix of Captain Parry's voyage for the discovery of a Northwest Passage, in the years 1819–20.* London, pp. 240–256.
1828. *Spicilegia Zoologica . . . Part I.* London. 12 pp.
1837. *A synoptical catalogue of the species of certain tribes or genera of shells contained in the collection of the British Museum and the author's cabinet; with descriptions of the new species.* Ann. Mag. Nat. Hist., new ser., vol. 1, pp. 370–376.
1840. *Synopsis of the contents of the British Museum.* Ed. 42, London. iv + 370 pp.
1847. *A list of the genera of Recent Mollusca, their synonyma and types.* Zool. Soc. London, Proc., vol. 15, pp. 129–219.
1848. *List of the specimens of British animals in the collections of the British Museum, Pt. L., Centroniae or radiated animals.* Brit. Mus., London, 173 pp.
1850. *Catalogue of Placentadae and Anomiadae.* In *Catalogue of the bivalve Mollusca in the British Museum.* London, pp. 1–22.
1853. *A revision of the genera of some of the families of Conchifera or bivalve shells.* Ann. Mag. Nat. Hist., ser. 2, vol. 11, pp. 33–44, 398–402.
1857. *A revision of the genera of some of the families of Conchifera or bivalve shells. Pt. 3, Arcadae.* Ann. Mag. Nat. Hist., ser. 2, vol. 19, pp. 366–373.

Gregorio, A.
1884. *Studi su talune conchiglie Mediterranee viventi e fossili con una rivista del gen.* Vulsella. Soc. Malac. Italiano, Bull., vol. 10, pp. 36–288, pls. 1–5.

Guppy, R. J. L.
1874. *On the West Indian Tertiary fossils.* Geol. Mag., (n.s.), dec. 2, vol. 1, No. 10, pp. 433–446, pl. 18.

Gustavson, T. C.
1972. *A warm-water Pleistocene fauna from the Gardiners Clay of Eastern Long Island.* J. Paleontol., vol. 46, No. 3, pp. 447–449.

Hampson, G. R.
1971. *A species pair of the genus* Nucula *(Bivalvia) from the Eastern coast of the United States.* Malac. Soc. London, Proc., vol. 39, No. 5, pp. 333–343.

Harmer, S. F.
1957. *The Polyzoa of the Siboga Expedition. Pt. 4. Cheilostomata Ascophora II.* Siboga Exped. Rept., vol. 28d, pp. 641–1145.

Harry, H. W.
1967. *A review of the living Tectibranch snails of the genus* Volvulella, *with descriptions of a new subgenus and species from Texas.* The Veliger, vol. 10, pp. 133–147.

Hartmann, J. D. W.
1821–1829. *System der Erd- und Süsswasser-Gasteropoden Europa's.* In Sturm, J., 1821–1829. *Deutschlands Fauna, in Abbildungen nach der Natur mit Beschreibungen.* Abt. 6, Hft. 5–8.

Hassall, A. H.
1841. *Supplement to a catalogue of Irish zoophytes.* Ann. Mag. Nat. Hist., vol. 7, pp. 363–373.

Hastings, A. B.
1968. *Some type and other specimens of species involved in the problem of* Stylopoma *Levinsen (Polyzoa).* Brit. Mus. (Nat. Hist.), Bull. Zool., vol. 16, No. 9, pp. 355–364.

Haq, B. U., Berggren, W. A., and Van Couvering, J. A.
1977. *Corrected age of the Pliocene–Pleistocene boundary.* Nature (London), vol. 269, pp. 483–488.

Hays, J. D., Imbrie, J., and Shackleton, N. J.
1976. *Variations in the Earth's Orbit: Pacemaker of the Ice Ages.* Science, vol. 194, pp. 1121–1132.

Hazel, J. E.
1970. *Binary coefficients and clustering in biostratigraphy.* Geol. Soc. Am. Bull., vol. 81, No. 11, pp. 3237–3252.
1971. *Ostracode biostratigraphy of the Yorktown Formation (upper Miocene and lower Pliocene) of Virginia and North Carolina.* U. S. Geol. Surv. Prof. Paper 704, 13 pp.
1977. *Distribution of some biostratigraphically diagnostic ostracodes in the Pliocene and lower Pleistocene of Virginia and northern North Carolina.* U. S. Geol. Surv., J. Res., vol. 3, No. 5, pp. 373–384.

Herrmannsen, A. N.
1852. *Indicis generum Malacozoorum. Supplementa et corrigenda,* Cassellis (Fischer) p. 140.

Hincks, T.
1877. *On British Polyzoa, Pt. 1.* Ann. Mag. Nat. Hist., ser. 4, pt. 1, vol. 20, pp. 212–218. *Pt. 2, (Classification).* pp. 520–532.
1880. *A history of the British marine Polyzoa.* John van Voorst, London, vols. 1–2, 601 pp.

Hoerle, S. E.
1970. *Mollusca of the "Glades" unit of Southern Florida. Part II: List of Molluscan species from the Belle Glade Rock Pit, Palm Beach County, Florida.* Tulane Studies in Geology and Paleontol., vol. 8, No. 2, pp. 55–68.

Hollister, S. C.
1958. *A review of the genus* Busycon *and its allies, Pt. 1.* Palaeontographica Americana, vol. 4, No. 28, pp. 47–126.

Holmes, F. S.
1860. *Post-Pliocene fossils of South Carolina.* Russell and Jones, Charlestown, 122 pp.

Hopkins, D. M., Rowland, R. W., and Patton, W. W., Jr.
1972. *Middle Pleistocene molluscs from St. Lawrence Island and their significance for the paleooceanography of the Bering Sea.* Quaternary Research, vol. 2, pp. 119–134.

Humphries, E. M.
1975. *A new approach to resolving the question of speciation in smittinid bryozoans (Bryozoa; Cheilostomata).* Vol. 3, No. 1, pp. 19–35. *In* Pouyet, E. (ed.), *Bryozoa, 1974, Proceedings of the Third Conference International Bryozoology Association.* Doc. Lab. Geologie, Fac. Sci. Lyons, hors ser. 3, fasc. 1, pp. 1–256.

Iredale, T.
1916. *On some new and old molluscan generic names.* Malacol. Soc. London, Proc., vol. 12, No. 1, pp. 27–37.

Jacobson, M. K., and Emerson, W. K.
1961. *Shells of the New York City area.* Argonaut Books, Larchmont, New York, 62 pp.

Jeffreys, J. G.
1865. *British conchology, or an account of the Mollusca which now inhabit the British Isles and the surrounding seas.* 5 vols., London. Vol. 1. *Land and fresh-water shells,* cxiv + 341 pp., 8 pls., 1862; vol. 2. *Marine shells, comprising the Brachiopoda and Conchifera from the family Anomiidae to that of Mactridae,* xiv + 465 pp., 8 pls., 1863; vol. 3. *Marine shells, comprising the remaining Conchifera, the Solenoconchia, and Gasteropoda as far as Littorina,* 393 pp., 8 pls., 1865; vol. 4. *Marine shells, in continuation of the Gasteropoda as far as the Bulla family,* 486 pp., 8 pls., 1867; vol. 5. *Marine shells and naked Mollusca to the end of the Gasteropoda, the Pteropoda, and Cephalopoda; with a supplement and other matter, concluding the work,* 258 pp., 102 pls., 1869.

Jenner, C. E.
1972. Personal communication, p. 123 *in* Wass, M. L., 1972. *A Check List of the Biota of the Lower Chesapeake.* Special Scientific Report No. 65, Virginia Institute of Marine Science, 290 pp.

Jenner, C. E., and McCrary, A. B.
1969. Paramya subovata, *a commensal with the echiuroid,* Thalessema hartmani. Am. Malacol. Union, Ann. Reports for 1969, pp. 42–43.

Johnson, C. W.
1934. *List of marine Mollusca of the Atlantic Coast from Labrador to Texas.* Boston Soc. Nat. Hist., Proc., vol. 40, No. 1, 204 pp.

Johnson, G. H.
1976. *Geology of the Mulberry Island, Newport News North, and Hampton Quadrangles, Virginia.* Virginia Div. Mineral Resources, Report of Investigations, vol. 41, 72 pp.

Johnson, G. H., and Goodwin, B. K.
1969. *Guidebook to the geology of the York–James Peninsula and south bank of the James River.* Atlantic Coastal Plain Geologic Association, 10th Annual Field Conference, and 1st Annual Virginia Geologic Field Conference. Williamsburg, Virginia, College of William and Mary (Department of Geology Guidebook 1), 33 pp.

Johnston, G.
1838. *A history of British zoophytes.* London, ed. 1, 333 pp.
1847. *A history of the British zoophytes.* John van Voorst, London, 2nd ed., 488 pp.

Jordan, R. R.
1974. *Pleistocene deposits of Delaware. In* Oaks, R. Q., Jr., and DuBar, J. R. (eds.), *Post-Miocene stratigraphy, central and southern Atlantic Coastal Plain.* Utah State Univ. Press, Logan, pp. 30–52.

Jousseaume, F. P.
1875. *Coquilles de la famille des Marginelles.* Rev. Mag. Zool., 3d ser., vol. 3, pp. 164–271; 429–435.

Jukes-Browne, A. J.
1905. *A review of the genera of the family Mytilidae.* Malac. Soc. London, Proc., vol. 6, pp. 211–224.

Jullien, J.
1903. *In* Jullien, J., and Calvert, L., *Bryozoaires provenant des Campagnes de l'Hirondelle (1886–1888).* Resultats Campagnes Sci. Yacht *Albert I, Monaco.* Fasc. 23, 188 pp., 18 pls. (pp. 1–120, pls. 1–15, by Jullien; pp. 120–188, pls. 16–18 by Calvert).

Keen, A. M.
1971. *Sea shells of tropical West America.* 2nd ed., Stanford Univ. Press, Stanford, 1064 pp.

Kiener, L. C.
1845. *Iconographie des coquilles vivantes.* Vol. 9, p. 15.

Kornfield, M. M.
1931. *Recent littoral foraminifera from Texas and Louisiana.* Contrib. Geol. Dept., Stanford Univ., vol. 1, pp. 77–107.

Kurtz, J. D.
1860. *Catalogue of the recent marine shells found on the coast of North and South Carolina.* Portland, David Tucker, 9 pp.

Kurtz, J. D., and Stimpson, W.
1851. *Descriptions of several new species of shells from the southern coast.* Boston Soc. Nat. Hist., Proc., vol. 4, pp. 114–115.

Lagaaij, R.
1952. *The Pliocene Bryozoa of Low Countries and their bearing on the marine stratigraphy of the North Sea region.* Nederl. Geol. Sticht., Meded., Ser. C, vol. 5, pp. 1–233.
1963. *New additions to the Bryozoan fauna of the Gulf of Mexico.* Inst. Mar. Sci., Univ. of Texas, Publ., vol. 9, pp. 162–236.

Lamarck, J. B. P. A.
1799. *Prodrome d'une nouvelle classification des coquilles, comprenant une rédaction appropriée des coquilles, comprenant une redaction appropriée des caractère génériques, et l'establissement d'un grand nombre de genres nouveaux.* Soc. Hist. Nat. Paris, Mem., pp. 63–90.
1801. *Système des animaux sans vertèbres ou tableau général des classes, des ordres et des genres de ces animaux.* Paris, 432 pp.
1802–1809. *Mémoires sur les fossiles des environs de Paris, comprenant la determination des espèces appartiennent aux animaux marines sans vertèbres, et dont la plupart sont figures dans la collection des vélins de Museum.* Mus. Nat. Hist. nat., Paris, Ann., vol. 1, pp. 299–312, 383–391, 474–478, 1802; vol. 2, pp. 57–64, 163–169, 217–227, 315–321, 385–391, 1803; vol. 3, pp. 163–170, 266–274, 343–352, 436–441, 1804; vol. 4, pp. 46–55, 105–115, 212–222, 289–298, 429–436, 1804; vol. 5, pp. 28–36, 91–98, 179–188, 237–245, 349–357, 1804; vol. 6, pp. 117–126, 214–228, pls. 1–4, pp. 337–345, 407–415, 1805; vol. 7, pp. 53–62, 130–139, 231–244, pls. 5–7, pp. 419–430, 1806; vol. 8, pp. 77–79, 156–166, 347–355, 383–388, 461–469, pls. 8–14, 1806; vol. 9, pp. 236–240, 399–401, pls. 15–20, 1807; vol. 12, pp. 456–459, pls. 21–24, 1808; vol. 14, pp. 374–375, pls. 25–28, 1809. [Reprinted 1978, Paleontological Research Inst., Ithaca, NY. 380 pp.]
1816–1822. *Histoire naturelle des animaux sans vertèbres.* pp. 2–3, 5–7.

Lamouroux, J. V.
1816. *Histoire des polypiers coralligens flexibles, vulgairement nommés zoophytes.* Caen, Poisson, 560 pp.

Latreille, P. A.
1825. *Familles naturelles du règne animal, exposées succintement et dans un ordre analytique, avec l'indication de leurs genres.* 570 pp., Paris.

Lea, H. C.
1842. *Description of eight new species of shells native to the United States.* Am. J. Sci., 1st ser., vol. 42, pp. 104–112.
1843. *Abstract of a Paper read before the American Philosophical Society, May 29, 1842, entitled "Description of some new Fossil Shells from the Tertiary of Petersburg, Virginia," by Henry C. Lea, Philadelphia.* 12 pp. Philadelphia.
1845. *Descriptions of some new Fossil Shells from the Tertiary of Petersburg, Virginia.* 45 pp. Philadelphia. (privately published)

Leach, W. E.
1817. *The Zoological Miscellany; being descriptions of new or interesting animals.* London, 3 vols. Vol. 1, pp. 1–144, pls. 1–60, 1814; vol. 2, pp. 1–154, pls. 61–120, 1815; vol. 3, pp. 1–149, pls. 120–149, 1817.

Levinsen, G. M. R.
1909. *Morphological and systematic studies on the Cheilostomatous Bryozoa.* Nationale Forfatteres Forlag., Kjobenhaven, 431 pp.

Lightfoot, J.
1786. *A catalog of the Portland Museum, lately the property of the Duchess Dowager of Portland, deceased, which will be sold at auction by Mr. Skinner and Co.,* London, viii + 194 pp.

Link, H. F.
1807. *Beschreibung der Naturalien-Sammlung der Universität zu Rostok.* vol. 1, pts. 2–4, 160 + 23 pp., 1807; pt. 6, 37 pp., 1808.

Linné, C. von
1758. *Systema naturae per regna tria naturae.* Editio decima, reformata, Stockholm, vol. 1, Regnum animale, 824 pp.
1767. *Systema naturae per regna tria naturae.* Editio duodecima, reformata, Stockholm, vol. 1, Regnum animale, Pt. 1, 532 pp.; Pt. 2, pp. 533–1327.

Linsley, J. H.
1845. *Catalogue of the shells of Connecticut.* Am. J. Sci., 1st ser., vol. 48, No. 2, pp. 271–286.

Lowman, S. W.
1949. *Sedimentary facies in Gulf Coast.* Am. Assoc. Petrol. Geol., Bull., vol. 33, No. 12, pp. 1939–1997.

Lozo, F. E., and Stricklin, F. L., Jr.
1956. *Stratigraphic notes on the outcrop basal Cretaceous, central Texas.* Gulf Coast Assoc. Geol. Soc., Trans., vol. 6, pp. 67–68.

MacNeil, F. S.
1938. *Species and genera of Tertiary Noetinae.* U. S. Geol. Surv. Prof. Paper 189A, 50 pp.
1965. *Evolution and distribution of the genus* Mya *with a discussion of Tertiary faunal migrations.* U. S. Geol. Surv. Prof. Paper 483G, 51 pp.

Mansfield, W. C.
1924. *A contribution to the late Tertiary and Quaternary pa-*

leontology of Northeastern Florida. Fifteenth Ann. Rept. Florida State Geol. Surv., pp. 25–51.
1928. *Notes on Pleistocene faunas from Maryland and Virginia and Pliocene and Pleistocene faunas from North Carolina.* U. S. Geol. Surv. Prof. Paper 150F, pp. 129–142.

Marcus, E. B.-R.
1972. *Notes on some opisthobranch gastropods from the Chesapeake Bay.* Chesapeake Sci., vol. 13, No. 4, pp. 300–317.

Marcus, E.
1938. *Bryozoarios marinhos brazileiros, Pt. 2.* São Paulo Univ., Fac. File Sci. Let., Bol. 4, pp. 1–137.

Martin, G. C.
1904. *Gastropoda.* Maryland Geol. Survey, Miocene, pp. 131–270, pls. 39–63.

Maturo, F. J. S., Jr.
1957. *A study of the Bryozoa of Beaufort, North Carolina and vicinity.* J. Elisha Mitchell Scient. Soc., vol. 73, No. 1, pp. 11–68.
1968. *The distributional pattern of the Bryozoa of the east coast of the United States exclusive of New England.* Att. Soc. It. Sc. Nat. e Museo Civ. St. Nat. Milano, vol. 108, pp. 261–284.

Maturo, F. J. S., Jr., and Schopf, T. J. M.
1968. *Ectoproct and entoproct type material: Re-examination of species from New England and Bermuda named by A. E. Verrill, J. W. Dawson, and E. Desor.* Postilla, vol. 120, pp. 1–95.

Maury, C. J.
1920. *Recent molluscs of the Gulf of Mexico and Pleistocene and Pliocene species from the Gulf States: Part 1, Pelecypoda.* Bull. Am. Paleontol., vol. 8, No. 34, pp. 1–115.
1922. *Recent Mollusca of the Gulf of Mexico and Pleistocene and Pliocene species from the Gulf States: Part 2, Scaphopoda, Gastropoda, Amphineura, Cephalopoda.* Bull. Am. Paleontol., vol. 9, No. 38, pp. 34–172.

Mazyck, W. G.
1913. *Catalogue of Mollusca of South Carolina.* Charleston Mus., Contribs., No. 2, pp. 14–39.

Meek, F. B.
1876. *A report on the invertebrate Cretaceous and Tertiary fossils of the upper Missouri country.* U. S. Geol. Surv. Terr. Report 9: xiv + 629 pp.

Merrill, A. S., Bullock, R. C., and Franz, D. R.
1978. *Range Extension of Mollusks from the Middle Atlantic Bight.* The Nautilus, vol. 92, pp. 34–40.

Meyer, O.
1888. *On Miocene invertebrates from Virginia.* Am. Philos. Soc., Proc., vol. 25, No. 27, pp. 135–144.

Michaud, A. L. G.
1828*. Bull. H. N. Soc. Linn. Bordeaux, vol. II, No. 10, p. 122.

Mighels, J. W.
1842. *Descriptions of new North American shells.* Boston Soc. Nat. Hist., Proc., vol. 4, pp. 345–349.

Mixon, R. B., Szabo, B. J., and Owens, J. P.
1982. *Uranium-series dating of molluscs and corals, and age of Pleistocene deposits, Chesapeake Bay area, Virginia and Maryland.* U. S. Geol. Surv. Prof. Paper 1067-E, pp. 1–18.

Moll, Johann Paul Carl von
1803. *Eschara ex zoophytorum se seu phytozoorum ....* Vindobonae, pp. 1–70.

* After much effort, we cannot find the complete reference for this citation. R.S.S., L.C.

Moller, H. P. C.
1842. *Index Molluscorum Groenlandiae.* Hafniae, 24 pp.

Montagu, G.
1803, 1808. *Testacea Britannica, or a natural history of British shells. Marine, land, and fresh water, including the most minute; systematically arranged and embellished with figures.* London, vols. 1–2, xxvi + 610 pp., pls. 1–16; suppl. 1808, 183 pp., pls. 17–30.

Monterosato, T. A. M. di
1889. *Coquilles marines Marocaines.* J. Conchyl., vol. 37, pp. 20–40.

Montifort, D.
1810. *Conchyliologie systêmatique et classification méthodique de coquilles.* vols. 1, 2, 676 pp.

Mörch, O. A. L.
1875–1877. *Synopsis Molluscorum Marinorum Indiarum Occidentalium imprimis Insularum Danicarum.* Malakozool. Blatter, vol. 22, pp. 142–184; vol. 23, pp. 45–58, 87–143; vol. 24, pp. 14–66, 93–123.

Morris, P.
1951. *A field guide to the shells of our Atlantic coast.* Houghton Mifflin Co., Boston, 190 pp.

Morrison, J. P. E.
1954. Hydrobia totteni, *new name for* Turbo minuta *(Totten, 1834) (Gastropoda: Hydrobiidae).* J. Wash. Acad. Sci., vol. 44, p. 26.
1965. *New brackish water mollusks from Louisiana.* Biol. Soc. Washington, Proc., vol. 78, pp. 217–224.
1971. *Western Atlantic* Donax. Bio. Soc. Washington., Proc., vol. 83, No. 48, pp. 545–568.

Mueller, O. F.
1875. *Entomostraca seu insecta testacea quae in aquis Daniae et Norvegiae reperit, descripsit et iconibus illustravit.* Lipsiae et Havniae, 135 pp., 21 pls.

Natland, M. L.
1938. *New species of foraminifera from off the west coast of North America and from the Later Tertiary of the Los Angeles Basin.* Scripps Institute Oceanog., Bull., Tech. Ser., vol. 4, No. 5, pp. 137–164.

Neviani, A.
1895. *Briozoi neozoici di alcune localita d'Italia. Part I.* Bol. Soc. Roma Studi Zool., vol. 4, pp. 109–123.

Newton, R. B.
1891. *Systematic List of the Frederick F. Edwards Collection of British Oligocene and Eocene Mollusca in the British Museum (Natural History).* London, xxviii + 365 pp.

Norman, A. M.
1876. *Report of the Polyzoa from the coasts of the Hebrides.* Rept. Brit. Assoc., vol. 36 (1866), pp. 193–206.
1903. *Notes on the natural history of East Finmark. Polyzoa (continued).* Ann. Mag. Nat. Hist., Ser. 7, vol. 12, pp. 87–128.

Oaks, R. G., Jr.
1964. *Post-Miocene stratigraphy and morphology, Outer Coastal Plain, Southeastern Virginia.* U. S. Office of Naval Research, Geography Branch, Tech. Rept. 5, Task Order NR388-064 (Yale University, Ph.D. dissert.), 240 pp.

Oaks, R. G., Jr., and Coch, N. K.
1963. *Pleistocene sea levels, Southeastern Virginia.* Science, vol. 140, pp. 970–983.
1968. *Post-Miocene tectonics of southeastern Virginia (abstr.).* Geol. Soc. America Spec. Paper 101, p. 272.

Oaks, R. G., Jr., and Coch, N. K.
1973. *Post-Miocene stratigraphy and morphology, Southeastern*

Virginia. Virginia Div. Min. Resources, Bull., vol. 82, viii + 135 pp.

Oaks, R. G., Jr., Coch, N. K., Sanders, J. E., and Flint, R. F.
1974. *Post-Miocene shorelines and sea levels, Southeastern Virginia. In* Oaks, R. Q., Jr., and DuBar, J. R. (eds.), *Post-Miocene stratigraphy, central and southern Atlantic Coastal Plain.* Utah State Univ. Press, Logan, pp. 53–87.

Oaks, R. Q., Jr., and DuBar, J. R.
1974. *Introduction. In* Oaks, R. Q., Jr., and DuBar, J. R. (eds.), *Post-Miocene stratigraphy, central and southern Atlantic Coastal Plain.* Utah State Univ. Press, Logan, pp. 2–10.

Oken, L.
1815. *Okens Lehrbuch der Naturgeschichte.* Leipzig, Jena, vol. 3, Zoologie, sect. 1, *Fleischose Thiere,* 842 pp., 40 pls.

Olsson, A. A.
1914. *New and interesting Neogene fossils from the Atlantic Coastal Plain.* Bull. Am. Paleontol., vol. 5, No. 24, pp. 1–24.
1916. *New Miocene fossils.* Bull. Am. Paleontol., vol. 5, No. 27, pp. 1–32.
1968. *A review of Late Cenozoic stratigraphy of southern Florida. In* Perkins, R. D. (ed.), *Late Cenozoic stratigraphy of southern Florida: a reappraisal.* Guideb. 2nd ann. fld. trip Miami Geol. Soc., pp. 66–82.

Olsson, A. A., and Harbison, A.
1953. *Pliocene Mollusca of southern Florida with special reference to those from North Saint Petersburg. With special chapters on Turridae by William G. Fargo and Vitrinellidae and fresh-water mollusks by Henry A. Pilsbry.* Acad. Nat. Sci. Philadelphia, Monogr., No. 8, 457 pp., 65 pls.

Olsson, A. A., and Petit, R.
1964. *Some Neogene Mollusca from Florida and the Carolinas.* Bull. Am. Paleontol., vol. 47, No. 217, pp. 505–575.

d'Orbigny, A.
1834–1847. *Voyage dans l'Amérique Méridionale (Le Brésil, La République Orientale de l'Uruguay, La République Argentine, La République du Chile, La République de Bolivia, La République du Perou), exécuté pendant les années 1826, 1827, 1828, 1829, 1830, 1831, 1832, et 1833.* Vol. 5, pt. 3, *Mollusques.* Paris, xiii + 758 pp., pls. 1–85.
1839. *Foraminifères. In* de la Sagra, *Histoire Physique, Politique et Naturelle de l'Ile de Cuba,* vol. 8, pp. 1–224.
1842. *Histoire physique, politique, et naturelle de l'Ile de Cuba par M. Ramon de la Sagra,* Atlas, 28 pls.
1845. *Historia fisica, politica, y natural de la isla de Cuba por D. Ramon de la Sagra, Segunda parte.* Historia Natural, vol. 5, Moluscas 376 pp.
1851–1854. *Paléontologie Française terrains crétacés, Tome 5, Bryozoaires.* Paris, Masson, 1192 pp.

Osburn, R. C.
1912. *The Bryozoa of the Woods Hole region.* Bur. Fish., Wash., Bull. 20, pp. 205–266.
1933. *The Bryozoa of the Mount Desert Region.* Biol. Surv. Mount Desert Region, Philadelphia, pt. 5, pp. 291–354.
1940. *Bryozoa of Puerto Rico with a resume of the West Indian Bryozoan fauna.* N. Y. Acad. Sci., Scient. Surv. Puerto Rico and Virgin Islands, vol. 16, No. 3, pp. 321–486.
1944. *A survey of the Bryozoa of the Chesapeake Bay.* Chesapeake Biol. Lab. Pub. 63, pp. 1–55.
1947. *Bryozoa of the Allan Hancock Atlantic expedition.* Rept. No. 5, pp. 1–66.
1952. *Bryozoa of the Pacific Coast of America. Part 2, Cheilostomata-Ascophora.* Allan Hancock Pacific Expedition, Rept. 14, No. 2, pp. 271–611.

Owens, J. P., and Denny, C. S.
1979. *Upper Cenozoic deposits of central Delmarva Peninsula.* U. S. Geol. Surv. Prof. Paper 1067-A, pp. 1–28.

Pallas, P. S.
1766. *Elenchus zoophytorum.* Hagae-Comitum. 451 pp.

Palmer, K. V. W.
1927. *The Veneridae of Eastern America, Cenozoic and Recent.* Palaeontographica Americana, vol. 1, No. 5, pp. 209–522.

Philippi, R. A.
1836. *Enumeratio Molluscorum Siciliae cum viventium tam tellure Tertaria fossilium, quae in itinere suo observavit.* vol. 1, xiv + 267 pp.
1847. *Testaceorum novorum centuria.* Zeitschr. f. Malakozool., yr. 4, pp. 71–77, 84–96, 113–127.
1849. *Centuria altera testaceorum novorum.* Zeitschr. f. Malakozool., yr. 5, pp. 123–176, 186–192.

Pilsbry, H. A.
1892. *A new marine Gasteropod from New Jersey.* Acad. Nat. Sci., Phila., Proc., for 1892, pt. 3, pp. 328–329.
1893. *A new Gastropod from New Jersey.* Nautilus, vol. 7, No. 6, pp. 67–68.
1953. *Part III-A, Vitrinellidae. In* Olsson, A. D., and Harbison, A., *Pliocene Mollusca of Southern Florida.* Acad. Nat. Sci. Phila., Monogr. No. 8, 457 pp., 65 pls.

Pilsbry, H. A., and McGinty, T. L.
1946a. *"Cyclostrematidae" and Vitrinellidae of Florida, Part III.* Nautilus, vol. 59, No. 3, pp. 77–83.
1946b. *Vitrinellidae of Florida, Part IV.* Nautilus, vol. 60, No. 1, pp. 12–18.
1950. *Vitrinellidae of Florida, Part V.* The Nautilus, vol. 63, No. 3, pp. 85–87.

Pilsbry, H. A., and Olsson, A. A.
1945. *Vitrinellidae and similar gastropods of the Panamic Province, Pt. 1.* Acad. Nat. Sci. Phila., Proc., vol. 97, pp. 249–278.

Poel, Luc van de
1959. *Faune malécologique du Hervien.* Inst. Roy. Sci. Nat. Belgique, Bull., vol. 35, Nos., 15, 16, pp. 1–26, 1–28.

Pojeta, J., Jr.
1971. *Review of Ordovician Pelecypods.* U. S. Geol. Surv. Prof. Paper 695, pp. 1–46.

Poli, G. S.
1791–1795. *Testacea utriusque Siciliae, eorumque historia et anatomia.* Parma, 2 vols. and atlas; vol. 3 continued by S. della Chiaje, 1827.

Porter, H. J.
1974. *The North Carolina marine and estuarine Mollusca—an atlas of occurrence.* Univ. of N. Carolina, Inst. of Marine Sci., Morehead City, NC, 351 pp.

Powell, N. A.
1967. *Polyzoa (Bryozoa)—Ascophora—from northern New Zealand.* "Discovery" Repts. 34, pp. 199–394.
1970. Schizoporella unicornis—*an alien Bryozoan introduced into the Strait of Georgia.* J. Fish. Res. Board, Canada, vol. 27, No. 10, pp. 1847–1853.

Powell, N. A., and Crowell, G. D.
1967. *Studies on Bryozoa (Polyzoa) of the Bay of Fundy region; Part I; Bryozoa from the intertidal zone of Minas Basin and Bay of Fundy.* Cah. Biol. Mar., vol. 8, pp. 331–347.

Prenant, M., and Bobbin, G.
1966. *Bryozoaires, Cheilostomes Anasca, 2ᵉ partie.* Faune de France, Paris, vol. 68, pp. 1–647.

Pultney, R.
1799. *Catalogues of the Birds, Shells, and some of the more rare*

Plants of Dorsetshire. From Hutchins, History of that county. London, 2d ed., 1813, folio.

Rafinesque, C. S.

1815. *Analyse de la Nature ou tableau de l'univers et des corps organisés.* Palermo. 224 pp.

1820. *Monografie des coquilles bivalves fluviatiles de la rivière Ohio.* Gen. Sci. Phys. Bruxelles, Ann., vol. 5, pp. 287–322.

Ravenel, E.

1834. *Catalog of Recent shells in the cabinet of Edmund Ravenel,* Charleston, 20 pp.

1861. *Descriptions of new Recent shells from the coast of South Carolina.* Acad. Nat. Sci. Phila., Proc., pp. 41–44.

Ray, C. E., Wetmore, A., Dunkle, D. H., and Drez, P.

1968. *Fossil vertebrates from the marine Pleistocene of Southeastern Virginia.* Smithsonian Misc. Coll., vol. 153, No. 3, pp. 1–25.

Redfield, J. H.

1860. *Descriptions of a new species of* Marginella. Acad. Nat. Sci. Phila., Proc., p. 174.

Reeve, L.

1843–1878. *Conchologia iconica; or illustrations of the shells of molluscous animals.* London, vols. 1–20, with suppl. to *Conus,* continued by Sowerby, G. G., II, beginning with the genus *Pyramidella* in vol. 15, Oct. 1865.

1844. *Conch. Icon.* Arca (pages not numbered).

1850. *Conch. Icon.,* vol. 6, Artemis.

Rehder, H. A.

1944. *A new* Vitrinella *from Maryland.* Nautilus, vol. 57, No. 3, p. 97.

1967. *Valid zoological names of the Portland Catalog.* U. S. Nat. Mus. Proc., vol. 121, No. 3579, pp. 1–49.

Richards, H. G.

1936. *Fauna of the Pleistocene Pamlico Formation of the southern Atlantic Coastal Plain.* Geol. Soc. Amer. Bull., vol. 47, pp. 1611–1656.

1944. *Notes on the geology and paleontology of the Cape May Canal, New Jersey.* Acad. Nat. Sci. Phila., Notulae Naturae No. 134, pp. 1–12.

1947. *Invertebrate fossils from deep wells along the Atlantic Coastal Plain.* J. Paleontol., vol. 21, pp. 23–42.

1962. *Studies on the marine Pleistocene, Part I. The marine Pleistocene of the Americas and Europe, Part II. The marine Pleistocene molluscs of Eastern North America.* Amer. Phil. Soc., Trans., n.s., vol. 52, pt. 3, 141 pp.

1966. *Pleistocene Pelecypoda of Virginia.* Virginia Minerals, vol. 12. No. 3, pp. 18–24.

1967. *Pleistocene Gastropoda of Virginia.* Virginia Minerals, vol. 13, No. 2, pp. 15–19.

Richards, H. G., and Campbell, L.

1972. *Additional Pleistocene molluscs of Virginia.* Virginia Minerals, vol. 18, No. 2, pp. 9–13.

Richards, H. G., and Ruhle, J. L.

1955. *Mollusks from a sediment core from the Hudson submarine canyon.* Penna. Acad. Sci., Proc., vol. 29, pp. 186–190.

Risso, J. A.

1826. *Histoire naturelle des principales productions de l'Europe Meridionale et particulièrement de celles des environs de Nice et des Alpes Maritimes.* Paris, E. G. Levrault, 5 vols. Vol. 4, *Aperçu sur l'histoire des mollusques qui vivent sur les bords de la Méditerranée boréale et des coquilles, terrestres fluviatiles, et marines, subfossiles, fossiles et petrifiées, qui gisent dans les diverses formations des Alpes Maritimes.* vii + 439 pp., 12 pls.

Röding, P. F.

1798. *Museum Boltenianum Sive Catalogus Cimeliorumetribus regnis naturae.* Hamburg. vii + 199 pp.

Rogick, M. D., and Croasdale, H.

1949. *Studies on marine bryozoa. Pt. III; Woods Hole region bryozoa associated with algae.* Biol. Bull. 96, No. 1, pp. 32–69.

Römer, E.

1857. *Kritische Untersuchung der Arten des Molluskengeschlechts* Venus *bei Linné und Gmelin mit Berucksichtigung der später beschriebenen Arten.* Marburg, xii + 135 pp.

Ruddiman, W. F.

1971. *Pleistocene sedimentation in the equatorial Atlantic, stratigraphy and faunal paleoclimatology.* Geol. Soc. Am., Bull., vol. 82, No. 2, pp. 283–301.

Ryland, J. S.

1965. *Catalogue of marine fouling organisms, No. 2, Polyzoa.* Organization for Economic Cooperation and Development, Paris, pp. 1–83.

1968. *On marine Polyzoa III:* Schizoporella ansata auct. . . . . J. Nat. Hist. (Ann. Mag. Nat. Hist.), vol. 2, pp. 535–546.

1969. *A nomenclatorial index to "A history of the British marine Polyzoa"* by T. Hincks (1880). British Museum (Nat. Hist.) Zool. Bull., vol. 17, No. 6, pp. 205–260.

Ryland, J. S., and Stebbing, A. R. D.

1971. *Two little known Bryozoans from the west of Ireland.* Irish Nat. J., vol. 17, No. 3, pp. 65–70.

Sacco, F.

1890–1904. *I molluschi dei terremi terziarii del Piemonte e della Liguria.* Pts. 6–30.

Sars, G. O.

1865. *Oversigt af Norges marine ostracoder.* Vidensk-Selks. Christiania Forth. 130 pp.

Say, T.

1820. *Observations on some species of zoophytes, shells, etc., principally fossil.* Am. J. Sci., 1st ser., vol. 2, pp. 34–40.

1822. *An account of some of the marine shells of the United States.* Acad. Nat. Sci. Phila., J. 1st ser., vol. 2, pp. 221–248, 257–276, 302–325.

1824. *An account of some fossil shells from Maryland.* Acad. Nat. Sci. Phila., J., 1st ser., vol. 4, pp. 124–155.

1826. *Descriptions of marine shells recently discovered on the coast of the United States.* Acad. Nat. Sci. Phila., J. 1st ser., vol. 5, pp. 207–221.

1827–1834. *American Conchology.* (pages unnumbered). Philadelphia.

Schopf, T. J. M.

1973. *Ergonomics of polymorphism: Its relation to the colony as the unit of natural selection in species of the Phylum Ectoprocta. In* Boardman, R. S., Cheetham, A. H., and Oliver, W. A., Jr. (eds.), *Animal colonies: Development and Function through time.* Dowden, Hutchinson and Ross, Stroudsburg, PA. pp. 247–294.

Schrank, F. P.

1798–1803. *Fauna Boica. Durchgedachte Geschichte der in Baiern einheimischen und zahmen Thiere.* Nürnberg. 3 vols.

Schumacher, C. F.

1817. *Essais d'un nouveau système des habitations des vers testacés.* Copenhagen, 287 pp., 22 pls.

Scolaro, R. J.
1970. *Notes on Miocene Bryozoa from northwestern Florida.* Tulane Studies in Geology and Paleontol., vol. 8, pp. 93–98.

Scopoli, G. A.
1777. *Introductio ad historium naturalem sistens genera lapidum, Plantarum et Animalium hactenus detecta, caracteribus essentiabilius donata, in tribus divisa, subinde ad leges naturae.* Prague. *Mollusca,* pp. 386–400.

Schideler, G. L., Swift, D. J. P., Johnson, G. H., and Holliday, B. W.
1972. *Late Quaternary stratigraphy of the inner Virginia Continental Shelf: A proposed standard section.* Geol. Soc. Am., Bull., vol. 83, No. 6, pp. 1787–1804.

Shier, D. E.
1964. *Marine Bryozoa from northwest Florida.* Bull. Mar. Sci., Gulf and Caribbean, vol. 14, No. 4, pp. 603–662.

Shupack, B.
1934. *Some Foraminifera from western Long Island Sound and New York Harbor.* Am. Mus. Nat. Hist. Novitates, No. 737, pp. 1–12.

Smith, S.
1860. *On the Mollusca of the Peconic and Gardiner's Bays, Long Island, New York.* Lyceum Nat. Hist. New York, Ann., vol. 7, pp. 147–168.

Smitt, A. F.
1873. *Floridan Bryozoa collected by Count L. F. de Pourtalès, Part 2.* K. Svenska Vetensk.-Akad., Handl., vol. 11, pp. 3–83.

Sokal, R. R., and Sneath, P. H. A.
1963. *Principles of numerical taxonomy.* Freeman, San Francisco, 359 pp.

Sowerby, G. B., I
1821–1834. *The genera of Recent and fossil shells.* London, 1: 1821–1825, pls. 1–126 and text (pages not numbered); 2: 1825–1834, pls. 127–262 and text (pages not numbered).

Sowerby, J.
1812–1846. *The mineral conchology of Great Britain; or coloured figures and descriptions of those remains of testaceous animals of shells, which have been preserved at various times and depths in the earth.* London, vols. 1–7. [Vols. 5–7 are by James de Carle Sowerby, the son of James Sowerby.]

Spengler, L.
1794. *Noiere Bestemmelse og Udvidelse af det Linneiske Genus* Solen. Skr. Naturhist. Selsk., pt. 2, vol. 3, pp. 81–114.
1798. *Over det toskallige Staegt Tellinerne.* Skr. Naturhist. Selsk. [Copen.]. vol. 9, pt. 2, pp. 67–121.

Stanley, S.
1970. *Relation of shell form to Life Habits in the Bivalvia (Mollusca).* Geol. Soc. Amer., Mem. 125, pp. 1–296.
1972. *Functional morphology and evolution of byssally-attached bivalve molluscs.* J. Paleontol., vol. 46, No. 2, pp. 165–212.

Stearns, R. E. C.
1873. *Descriptions of new species of marine molluscs from the coast of Florida.* Boston Soc. Nat. Hist., Proc., vol. 15, pp. 21–24.

Stephenson, L. W.
1928. *Major marine transgressions and regressions and structural features of the Gulf Coastal Plain.* Am. J. Sci., 5th ser., vol. 16, pp. 281–298.

Stimpson, W.
1851. *Shells of New England. A revision of the synonymy of the Testaceous molluscs of New England with notes on their structure and on their geographical and bathymetric distribution.* Boston, 58 pp.
1854. *On some remarkable marine invertebrata inhabiting the shores of South Carolina.* Boston Soc. Nat. Hist., Proc., vol. 5, pp. 110–117.
1858. *Review of "Natur historiske bidrag til en Belkrivelle of Grønland" by Reinhardt. J., Schiodte, J. C., Mörch, O. A. L., Lutkin, C. F., Lange, J., and Rink, H.* Copenhagen, 1857. Am. J. Sci., vol. 25, pp. 124–126.
1865. *On certain genera and families of zoophagous gasteropods.* Am. J. Conchol., vol. 1, pt. 1, No. 12, pp. 55–64, pls. 8–9.

Stoliczka, F.
1870–1871. *The Pelecypoda, with a review of all known genera of this class, fossil and Recent.* Geol. Survey India, Mem., Paleontol. Indica, Cretaceous fauna, vol. 3, xxii + 538 pp., pls. 1–50.

Sumner, F. B., Osburn, R. C., and Cole, L. J.
1913. *A biological survey of the waters of Woods Hole and vicinity, Section 1—Physical and zoological.* U. S. Bur. Fisheries, Bull. 31, pp. 1–860.

Swainson, W.
1831. *Zoological illustrations or original figures and descriptions of new, rare, or interesting, animals, selected chiefly from the classes of ornithology, entomology, and conchology, arranged according to their apparent affinities.* London, ser. 1, 1820–23, vol. 1, 66 pls., vol. 2, pls. 67–119; vol. 3, pls. 120–182; ser. 2, 1831–32, vol. 2, Nos. 11–20, pls. 46–91.
1840. *A treatise on malacology or shells and shell-fish.* London, 419 pp.

Thiele, J.
1925. *Gastropoda der Deutsche Tiefsee-Expedition. 2.* Wiss. Ergebn. 'Valdivia,' vol. 17, No. 2, pp. 26–382, pls. 13–46.
1929–1935. *Handbuch der systematischen Weichtierkunde.* Jena, vol. 1, pt. 1, pp. 1–376 (1929); pt. 2, pp. 377–778, figs. 1–783 (1931); vol. 2, pt. 3, pp. 779–1022 (1934); pt. 4, pp. 1023–1154, figs. 784–879 (1935).

Totten, J.
1834. *Description of some new shells belonging to the coast of New England.* Am. J. Sci., vol. 26, pp. 366–369.
1835. *Description of some shells belonging to the coast of New England.* Am. J. Sci., vol. 28, pp. 347–353.

Tryon, G. W., Jr.
1862. *On the classification and synonymy of the Recent species of Pholadidae.* Acad. Nat. Sci. Philadelphia, Proc., vol. 14, pp. 191–221.

Tuomey, M., and Holmes, F. S.
1855–1857. *Pliocene fossils of South Carolina containing descriptions and figures of the Polyporia, Echinodermata, and Mollusca.* Russel and Jones, Charleston, S. C., 152 pp.

Turner, R.
1954. *The Family Pholadidae in the Western Atlantic and the Eastern Pacific: Part I, Pholadinae.* Johnsonia, vol. 3, pp. 1–64.
1955. *The Family Pholadidae in the Western Atlantic and the Eastern Pacific: Part II, Martesiinae, Johanetiinae, and Xylophaginae.* Johnsonia, vol. 3, pp. 65–160.

Turton, W.
1822. *Conchylia dithyra insularum Britannicarum. The bivalve shells of the British Islands.* London, 279 pp., 20 pls.

Ulrich, E. O., and Bassler, R. S.
1904. *Systematic Paleontology, Miocene, Bryozoa. In* Clark, W. B., Shattuck, G. B., and Dall, W. H., *Miocene.* Maryland Geol. Surv., pp. 404–429, pls. 109–118.

Valentine, P. C.
1971. *Climatic implications of a late Pleistocene Ostracode as-*

semblage from Southeastern Virginia. U. S. Geol. Surv., Prof. Paper 683D, 28 pp.

Vélain, C.

1877. *Expedition française aux îles Saint Paul et Amsterdam. Zoologie Description des mollusques.* Arch. Zool. Exper. Gen., vol. 6, pp. 96–144, 4 pls.

Vernburg, F. J., and Vernburg, W. B.

1970. *Lethal limits and the zoogeography of the faunal assemblages of coastal Carolina waters.* Marine Biology, vol. 6, No. 1, pp. 26–32.

Verrill, A. E.

1875a. *Brief contributions to zoology from the museum of Yale College. No. XXXII. Results of dredging expeditions of the New England coast in 1874.* Am. J. Sci., 3rd ser., vol. 9, pp. 411–415.

1875b. *Brief contributions to zoology from the museum of Yale College. No. XXXIII. Results of dredging expeditions off the New England coast in 1874.* Am. J. Sci., 3rd ser., vol. 10, pp. 36–43.

1879. *Preliminary checklist of the marine invertebrata of the Atlantic Coast from Cape Cod to the Gulf of St. Lawrence.* (prepared for the U. S. Commission of Fish and Fisheries), Author's Edition, Tuttle, Moorehours, and Taylor, printers, New Haven, Conn.

1882. *Catalog of marine Mollusca added to the fauna of the New England region during the past ten years.* Conn. Acad. Arts and Sci., Trans., vol. 5, pp. 447–487.

1884. *Second catalogue of Mollusca recently added to the fauna of New England Coast and the adjacent parts of the Atlantic, consisting mostly of deep-sea species, with notes on others previously recorded.* Conn. Acad. Arts and Sci., Trans., pt. 6, vol. 6, pp. 139–289.

Verrill, A. E., and Smith, S. I.

1873. *Report upon the invertebrate animals of Vineyard Sound and the adjacent waters.* Report of the U. S. Fish Commission, 1871–72, pp. 295–778, 38 pls., Washington.

Vokes, H. E.

1957. *Miocene Fossils of Maryland.* Maryland Geol. Survey, Bull. 20, 85 pp.

Waller, T. R.

1969. *The evolution of the* Argopecten gibbus *stock (Mollusca: Bivalvia) with emphasis on the Tertiary and Quaternary species of eastern North America.* Paleontol. Soc. Mem. 3 [supplement to J. Paleontol., vol. 43, No. 5], pp. 1–125.

Warmke, G., and Abbott, R. T.

1961. *Caribbean sea shells.* Livingston, Narberth, ix + 346 pp.

Wass, M.

1965. *Check list of the marine invertebrates of Virginia.* Special Scientific Rept. No. 24, Virginia Inst. Mar. Sci., Gloucester Point.

1972. *A check list of the Biota of Lower Chesapeake Bay.* Special Scientific Rept. No. 65, Virginia Inst. Mar. Sci., 290 pp.

Waters, A. W.

1878. *The use of the opercula in the determination of the Cheilostomous Bryozoa.* Maunch. Lit. Phila. Soc., Proc., vol. 18, pp. 8–11.

Watson, R. B.

1883. *Mollusca of H. M. S.* "Challenger" *Expedition, Pt. XV.* J. Linn. Soc. London, XVII: vol. 325, pp. 319–346.

1886. *Report on the Scaphopoda and Gastropods.* Rep. Scient. Res. Voy. H. M. S. Challenger 1873–76. Zoology 15, pt. 42, 756 pp., 53 pl.

Weisbord, N. E.

1967. *Some late Cenozoic Bryozoa from Cabo Blanco, Venezuela.* Bull. Am. Paleontol., vol. 53, pp. 1–247.

Wells, H. W.

1961. *The fauna of oyster beds with special reference to the salinity factor.* Ecological Monographs, vol. 31, pp. 239–266.

Wells, H. W., and Wells, M. J.

1961. *Three species of* Odostomia *from North Carolina with descriptions of new species.* Nautilus, vol. 74, No. 4, pp. 149–157.

Wenz, W.

1938–1944. *"Handbuch der Paläozoologie,"* (Schindewolf, O., ed.), *"Gastropods,"* vol. 6, pts. 1–7, Gebrüder Borntraeger, Berlin.

Whitehead, D. R.

1972. *Developmental and environmental history of the Dismal Swamp.* Ecological Monographs, vol. 42, pp. 301–315.

Winkley, H. W.

1908. *A new* Caecum. Nautilus, vol. 22, No. 6, p. 54.

Wood, S. V.

1848. *The Crag Mollusca.* The Palaeontographical Society, Monographs, vol. 1, 208 pp.

Woodring, W. P.

1928. *Miocene mollusks from Bowden, Jamaica. Pt. 2, Gastropods and discussion of results.* Carnegie Inst. Washington, Publ. No. 385, 460 pp., 40 pls.

Woodward, S.

1833. *Geology of Norfolk.* London, p. 44.

Woolman, L.

1898. *Fossil mollusks and diatoms from the Dismal Swamp, Virginia and North Carolina.* Acad. Nat. Sci. Philadelphia, Proc. for 1898, pp. 414–428.

Woolman, L., and Boyer, C. S.

1898. *Fossil molluscs and diatoms from the Dismal Swamp, Virginia and North Carolina; indication of the geological age of the deposit.* Acad. Nat. Sci. Phila., Proc., pp. 414–428.

Young, K. P.

1963. *Mesozoic history of the Llano region.* Univ. Texas Bur. Econ. Geology Guidebook No. 5, pp. 98–106. (Modified and reprinted from Geology of the Gulf Coast and Central Texas, published by Houston Geol. Soc. for 1962 Ann. Meeting of Geol. Soc. Am., 1962.)

Zellner, L. R.

1979. [MS] *Development and Application of a Pleistocene Sea Level Curve to the Coastal Plain of Southeastern Virginia.* School of Marine Science, The College of William and Mary in Virginia. 85 pp., M.S. thesis.

Zinsmeister, W. J.

1974. *A new interpretation of thermally-anomalous molluscan assemblages of the California Pleistocene.* J. Paleontol., vol. 48, No. 1, pp. 84–94.

EXPLANATION OF PLATE 1

(All illustrated specimens ×60)
(All are external views, unless otherwise specified)

Figure — Page

1, 4. ***Membranipora tenuis*** Desor ... 28
Locality 22b, Norfolk Member.
Hypotype: USNM 218151.

2. ***Electra monostachys*** (Busk) ... 28
Locality 22b, Norfolk Member.
Hypotype: USNM 218152.

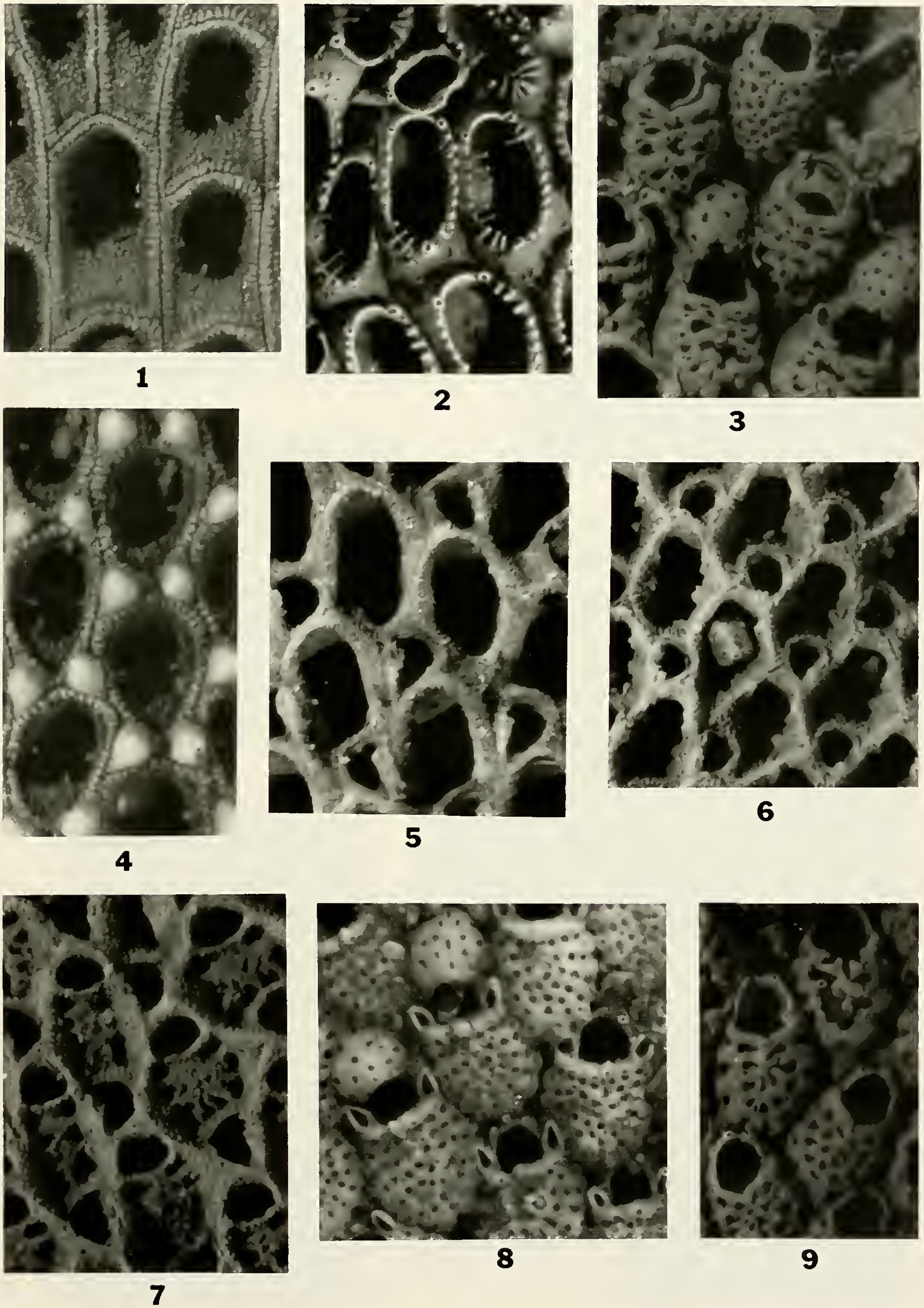
3, 8. ***Cribrilina punctata*** (Hassall) ... 31
3. Locality 17d, Norfolk Member.
Hypotype: USNM 218156.
8. Locality 17d, Norfolk Member.
Hypotype: USNM 218303.

5. ***Cupuladria biporosa*** Canu and Bassler ... 29
Locality 18d, Norfolk Member.
Hypotype: USNM 218153.

6. ***Cupuladria owenii*** (Gray) ... 29
Locality 18d, Norfolk Member.
Hypotype: USNM 218154.

7. ***Discoporella umbellata depressa*** (Conrad) ... 30
Locality 18d, Norfolk Member.
Hypotype: USNM 218155.

9. ***Membraniporella*** cf. ***Membraniporella petasus*** Canu and Bassler ... 31
Locality 17d, Norfolk Member.
Hypotype: USNM 218157.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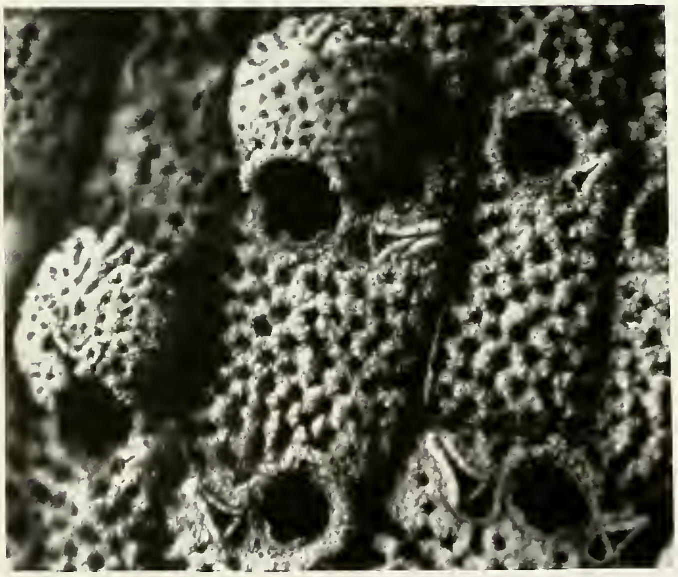

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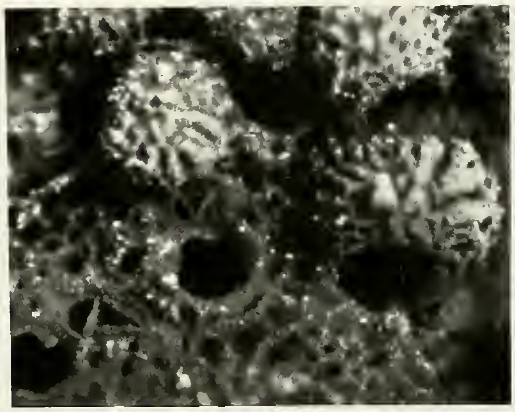

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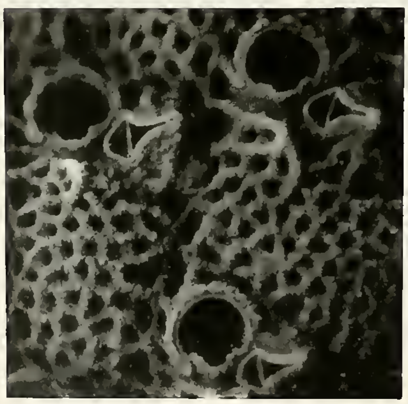

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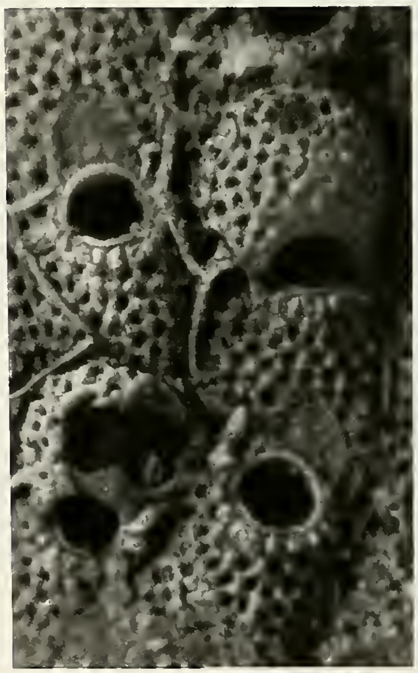

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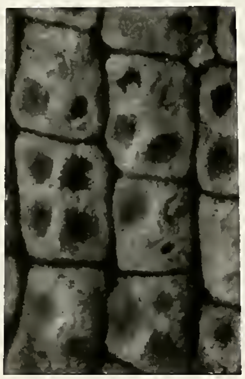

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EXPLANATION OF PLATE 2

(All illustrated specimens ×60)
(All are external views, unless otherwise specified)

Figure — Page

1, 3–5. ***Schizoporella errata*** (Waters) 34
  1. Locality 17e, Norfolk Member, showing flattened frontal and two sizes of avicularia in proximolateral positions. Hypotype: USNM 218158.
  3. Locality 17d, Norfolk Member, showing double proximolateral avicularia of unequal size and heavily ridged ovicell. Hypotype: USNM 218159.
  4, 5. Locality 17d, Norfolk Member. Hypotype: USNM 218160.

2. ***Stephanosella cornuta*** (Gabb and Horn) 35
Locality 22b, Norfolk Member.
Hypotype: USNM 218161.

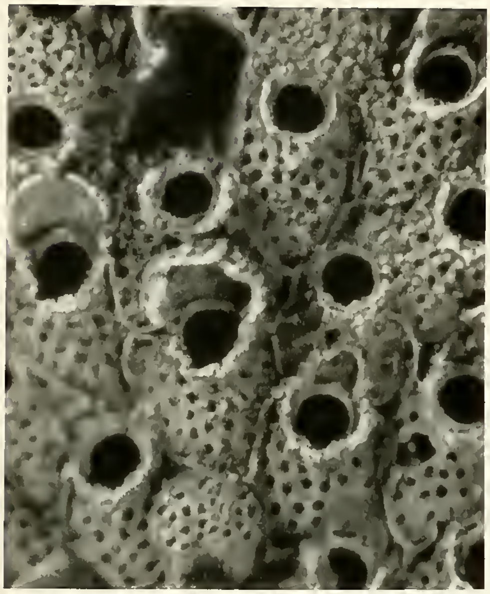
6. ***Hippoporina porosa*** (Verrill) 32
Locality 17d, Norfolk Member.
Hypotype: USNM 218162.

7. ***Cupuladria biporosa*** Canu and Bassler 29
Locality 18d, Norfolk Member, showing basal side.
Hypotype: USNM 218153.

EXPLANATION OF PLATE 3

(All illustrated specimens ×60)
(All are external views, unless otherwise specified)

Figure	Page
1. ***Hippoporina*** cf. ***H. verrilli*** Maturo and Schopf Locality 18d, Norfolk Member. Hypotype: USNM 218163.	33
2. ***Hippoporidra calcarea*** (Smitt) Locality 22b, Norfolk Member. Hypotype: USNM 218164.	35
3. ***Microporella ciliata*** (Pallas) Locality 17d, Norfolk Member. Hypotype: USNM 218165.	36
4. ***Parasmittina nitida*** (Verrill) Locality 20b, Norfolk Member. Hypotype: USNM 218166.	37
5. ***Cryptosula pallasiana*** (Moll) Locality 22b, Norfolk Member. Hypotype: USNM 218167.	38
6. ***Cupuladria owenii*** (Gray) Locality 18d, Norfolk Member, showing basal side. Hypotype: USNM 218154.	29
7. ***Discoporella umbellata depressa*** (Conrad) Locality 18d, Norfolk Member, showing basal side. Hypotype: USNM 218155.	30



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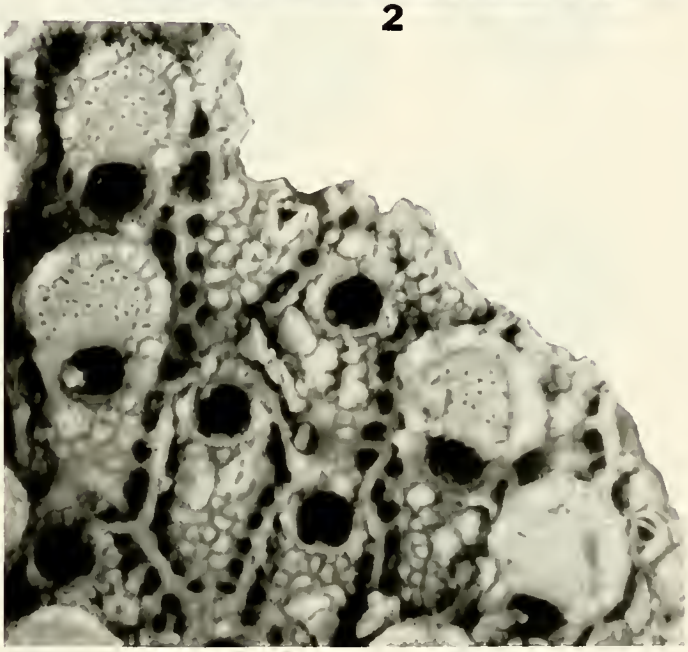

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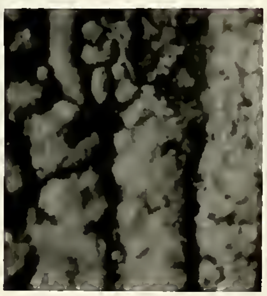

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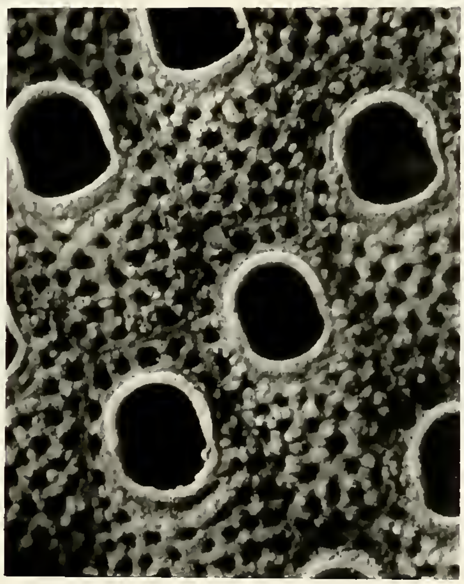

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Explanation of Plate 4

Figure Page

1, 2. ***Solemya velum*** Say 39
1. Right valve, exterior, ×1.
2. Right valve, interior, ×1.
Locality 17c, Kempsville Member.
Hypotype: USNM 218168.

3, 4. ***Nucula major*** Richards 38
3. Right valve, exterior, ×1.5.
4. Right valve, interior, ×1.5.
Locality 23, Kempsville Member.
Hypotype: ANSP 64321.

5, 6. ***Nucula proxima*** Say 38
5. Left valve, exterior, ×4.
6. Left valve, interior, ×4.
Locality 17d, Norfolk Member.
Hypotype: USNM 218170.

7, 8. ***Nuculana acuta*** (Conrad) 39
7. Left valve, exterior, ×4.
8. Left valve, interior, ×4.
Locality 17e, Norfolk Member.
Hypotype: USNM 218171.

9, 10. ***Anadara ovalis*** (Bruguière) 39
9. Right valve, exterior, ×1.
10. Right valve, interior, ×1.
Locality 17e, Norfolk Member.
Hypotype: USNM 218172.

11, 12. ***Anadara transversa*** (Say) 40
11. Right valve, exterior, ×1.
12. Right valve, interior, ×1.
Locality 17d, Norfolk Member.
Hypotype: USNM 218173.

13, 14. ***Modiolus squamosus*** Beauperthuy 41
13. Left valve, exterior, ×0.5.
14. Left valve, interior, ×0.5.
Locality 17d, Norfolk Member.
Hypotype: USNM 218177.

15–17, 21. ***Noetia (Eontia) ponderosa*** (Say) 40
15. Left valve, exterior, ×0.75.
16. Left valve, interior, ×0.75.
Locality 17c, Kempsville Member.
Hypotype: USNM 218174.
17. Right valve, exterior, ×1.
21. Right valve, interior, ×1.
Locality: Pleistocene, Horry Co., SC.
Hypotype: USNM 218175.

18, 19. ***Mytilus edulis*** Linné 40
18. Left valve, exterior, ×1.5.
19. Left valve, interior, ×1.5.
Locality 17c, Kempsville Member.
Hypotype: USNM 218176.

20. ***Musculus lateralis*** (Say) 42
20. Left valve, exterior, ×4.
Locality 17c, Kempsville Member.
Hypotype: USNM 218178.

EXPLANATION OF PLATE 5

Figure	Page

1, 8. ***Crassostrea virginica*** (Gmelin) 42
1. Right valve, exterior, ×0.75.
8. Right valve, interior, ×0.75.
Locality 17c, Kempsville Member.
Hypotype: USNM 218179.

2, 5. ***Argopecten gibbus*** (Linné) 42
2. Right valve, exterior, ×0.75.
5. Right valve, interior, ×0.75.
Locality 18a, Sand Bridge Member.
Hypotype, USNM 218180.

3, 6. ***Anomia simplex*** d'Orbigny 42
3. Right valve, exterior, ×1.2.
6. Right valve, interior, ×1.2.
Locality 17d, Norfolk Member.
Hypotype: USNM 218181.

4, 7. ***Astarte castanea*** (Say) 45
4. Right valve, exterior, ×1.
7. Right valve, interior, ×1.
Locality 23.
Hypotype: USNM 218182.

9, 10. ***Crassinella lunulata*** (Conrad) 46
9. Left valve, exterior, ×7.
10. Left valve, interior, ×7.
Locality 17c, Kempsville Member.
Hypotype: USNM 218183.

11, 12. ***Cyclocardia borealis*** (Conrad) 45
11. Right valve, exterior, ×1.2.
12. Right valve, interior, ×1.2.
Locality 23, Kempsville Member.
Hypotype: USNM 218184.

13, 14. ***Pleuromeris tridentata*** (Say) 45
13. Left valve, exterior, ×4.
14. Left valve, interior, ×4.
Locality 21, Norfolk Member.
Hypotype: USNM 218185.

15, 19. ***Parvilucina multilineata*** (Tuomey and Holmes) 43
15. Left valve, exterior, ×7.5.
19. Left valve, interior, ×7.5.
Locality 18d, Norfolk Member.
Hypotype: USNM 218186.

16, 20. ***Codakia costata*** (d'Orbigny) 43
16. Left valve, exterior, ×4.
20. Left valve, interior, ×4.
Locality 18e, Great Bridge Member.
Hypotype: USNM 218169.

17, 18. ***Divalinga quadrisulcata*** (d'Orbigny) 43
17. Right valve, exterior, ×1.
18. Right valve, interior, ×1.
Locality 18d, Norfolk Member.
Hypotype: USNM 218187.


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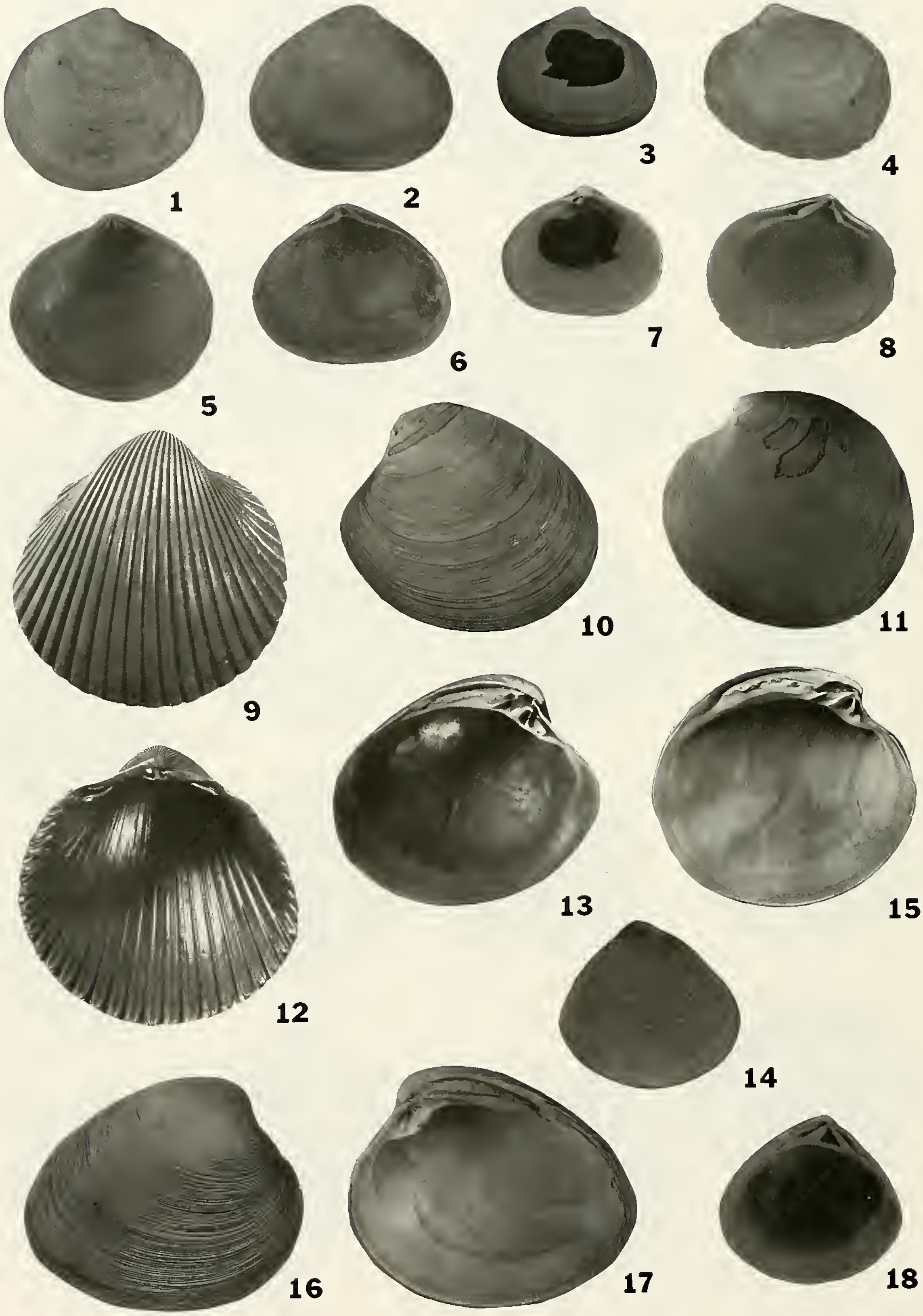
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EXPLANATION OF PLATE 6

Figure	Page
1, 5. ***Diplodonta punctata*** (Say)	44
1. Right valve, exterior, ×4.
5. Right valve, interior, ×4.
Locality 18b, Sand Bridge Member.
Hypotype: USNM 218188.
2, 6. ***Bornia longipes*** (Stimpson)	44
2. Right valve, exterior, ×4.
6. Right valve, interior, ×4.
Locality 17c, Kempsville Member.
Hypotype: USNM 218189.
3, 7. ***Aligena elevata*** (Stimpson)	44
3. Right valve, exterior, ×9.
7. Right valve, interior, ×9.
Locality 19, Sand Bridge Member.
Hypotype: USNM 218190.
4, 8. ***Mysella planulata*** (Stimpson)	44
4. Left valve, exterior, ×7.5.
8. Left valve, interior, ×7.5.
Locality 19, Sand Bridge Member.
Hypotype: USNM 218191.
9, 12. ***Dinocardium robustum*** (Lightfoot)	46
9. Right valve, exterior, ×1.
12. Right valve, interior, ×1.
Locality 21, Norfolk Member.
Hypotype: USNM 218192.
10, 13. ***Pitar morrhuana*** (Linsley)	51
10. Left valve, exterior, ×1.
13. Left valve, interior, ×1.
Locality 17d, Norfolk Member.
Hypotype: USNM 218304.
11, 15. ***Dosinia discus*** (Reeve)	52
11. Left valve, exterior, ×0.5.
15. Left valve, interior, ×0.5.
Locality 17e, Norfolk Member.
Hypotype: USNM 218194.
14, 18. ***Gemma purpurea*** (Lea)	52
14. Left valve, exterior, ×7.5.
18. Left valve, interior, ×7.5.
Locality 17c, Kempsville Member.
Hypotype: USNM 218193.
16, 17. ***Mercenaria mercenaria*** (Linné)	51
16. Right valve, exterior, ×0.5.
17. Right valve, interior, ×0.5.
Locality 17c, Norfolk Member.
Hypotype: USNM 218195.

EXPLANATION OF PLATE 7

Figure ... Page

1–3, 6. ***Mercenaria campechiensis*** (Gmelin) ... 51
1. Left valve, exterior, ×0.5.
2. Left valve, interior, ×0.5.
Locality 17b, Kempsville Member.
Hypotype: USNM 218196.
3. Right valve, exterior, ×0.75.
6. Right valve, interior, juvenile, ×0.75.
Locality 17b, Kempsville Member.
Hypotype: USNM 409332.

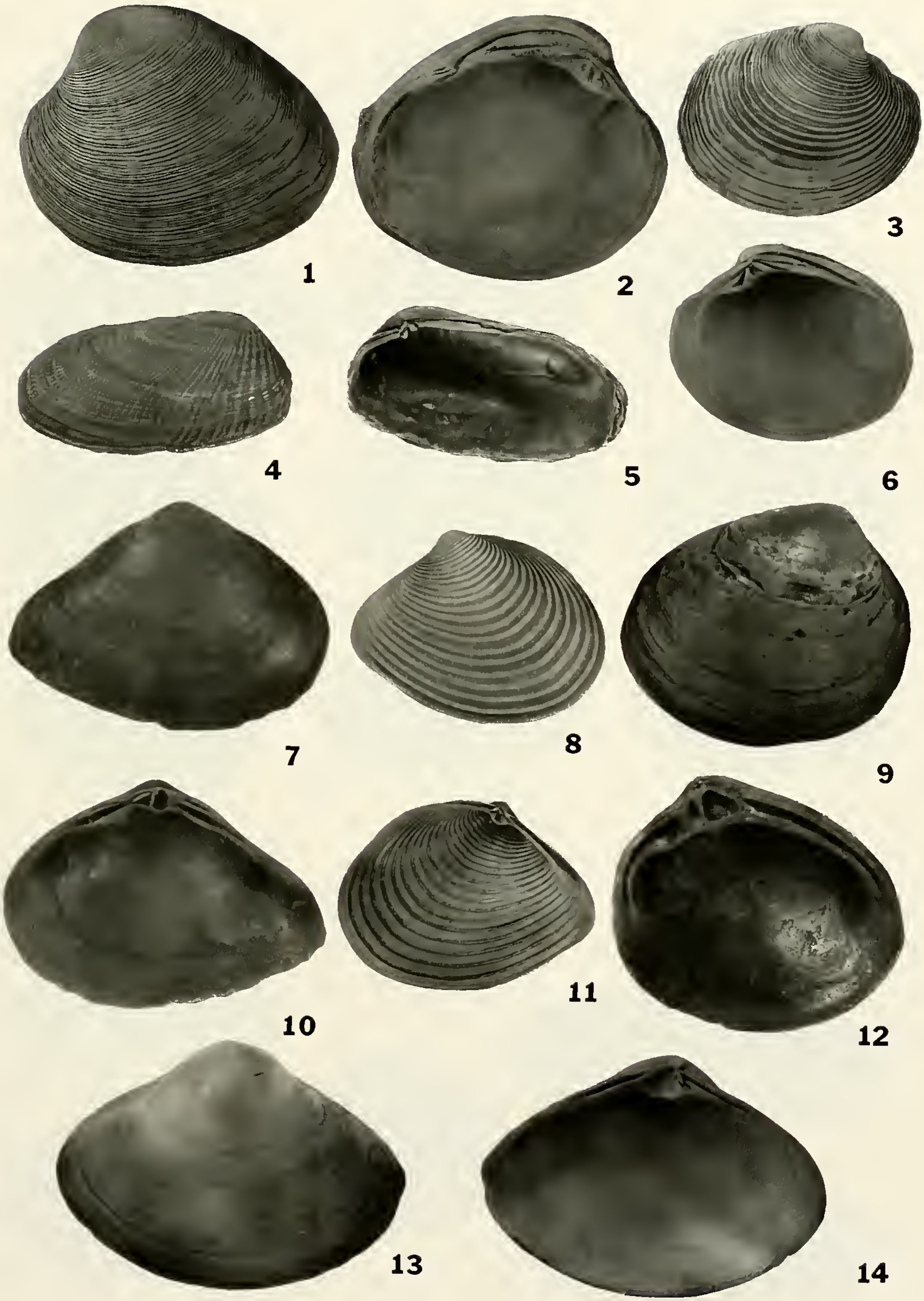
4, 5. ***Petricola pholadiformis*** Lamarck ... 52
4. Right valve, exterior, ×1.
5. Right valve, interior, ×1.
Locality 18d, Norfolk Member.
Hypotype: USNM 218197.

7, 10. ***Mulinia lateralis*** (Say) ... 47
7. Right valve, exterior, ×3.
10. Right valve, interior, ×3.
Locality 17f, Great Bridge Member.
Hypotype: USNM 218198.

8, 11. ***Raeta plicatella*** (Lamarck) ... 47
8. Right valve, exterior, ×0.75.
11. Right valve, interior, ×0.75.
Recent beach deposit, VA/NC state line.
Hypotype: USNM 218199.

9, 12. ***Rangia cuneata*** (Sowerby) ... 47
9. Right valve, exterior, ×2.
12. Right valve, interior, ×2.
Locality 18b, Sand Bridge Member.
Hypotype: USNM 218200.

13, 14. ***Spisula solidissima*** (Dillwyn) ... 46
13. Left valve, exterior, ×0.75.
14. Left valve, interior, ×0.75.
Locality 17b, Kempsville Member.
Hypotype: USNM 218201.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EXPLANATION OF PLATE 8

Figure		Page
1, 4.	***Tellina agilis*** Stimpson	48
	1. Left valve, exterior, ×3.	
	4. Left valve, interior, ×3.	
	Locality 17c, Kempsville Member.	
	Hypotype: USNM 218204.	
2, 5.	***Tellina texana*** Dall	49
	2. Right valve, exterior, ×4.	
	5. Right valve, interior, ×4.	
	Locality 17c, Kempsville Member.	
	Hypotype: USNM 218203.	
3, 6.	***Tellina alternata*** Say	48
	3. Left valve, exterior, ×1.2.	
	6. Left valve, interior, ×1.2.	
	Locality 18e, Great Bridge Member.	
	Hypotype: USNM 218202.	
7, 8.	***Macoma balthica*** (Linné)	49
	7. Right valve, exterior, ×1.5.	
	8. Right valve, interior, ×1.5.	
	Locality 18e, Great Bridge Member.	
	Hypotype: USNM 218205.	
9, 12.	***Macoma constricta*** (Bruguière)	49
	9. Left valve, exterior, ×0.75.	
	12. Left valve, interior, ×0.75.	
	Locality 17f, Great Bridge Member.	
	Hypotype: USNM 218206.	
10, 11.	***Donax roemeri protracta*** (Conrad)	49
	10. Left valve, exterior, ×4.5.	
	11. Left valve, interior, ×4.5.	
	Locality 26, Norfolk Member.	
	Hypotype: USNM 218207.	
13, 14.	***Donax parvula*** Philippi	49
	13. Left valve, exterior, ×5.	
	14. Left valve, interior, ×5.	
	Locality 17c, Kempsville Member.	
	Hypotype: USNM 218208.	
15, 17.	***Tagelus divisus*** (Spengler)	50
	15. Left valve, exterior, ×1.5.	
	17. Left valve, interior, ×1.5.	
	Locality 18e, Great Bridge Member.	
	Hypotype: USNM 409329.	
16, 18.	***Tagelus plebeius*** (Lightfoot)	51
	16. Right valve, exterior, ×0.75.	
	18. Right valve, interior, ×0.75.	
	Locality 17f, Great Bridge Member.	
	Hypotype: USNM 218209.	
19, 20.	***Semele*** cf. ***S. purpurascens*** (Gmelin)	50
	19. Left valve, exterior, ×4.	
	20. Left valve, interior, ×4.	
	Locality 17c, Kempsville Member.	
	Hypotype: USNM 218210.	

EXPLANATION OF PLATE 9

Figure — Page

1, 4. ***Abra aequalis*** (Say) 50
- 1. Right valve, exterior, ×3.
- 4. Right valve, interior, ×3.
- Locality 18d, Norfolk Member.
- Hypotype: USNM 218211.

2, 5. ***Cumingia tellinoides*** (Conrad) 50
- 2. Left valve, exterior, ×2.
- 5. Left valve, interior, ×2.
- Locality 17c, Kempsville Member.
- Hypotype: USNM 218212.

3, 6. ***Mya arenaria*** Linné 53
- 3. Right valve, exterior, ×0.75.
- 6. Right valve, interior, ×0.75.
- Locality 22c, Great Bridge Member.
- Hypotype: USNM 218214.

7, 8. ***Ensis directus*** (Conrad) 48
- 7. Left valve, exterior, ×0.5.
- 8. Left valve, interior, ×0.5.
- Locality 17d, Norfolk Member.
- Hypotype: USNM 218213.

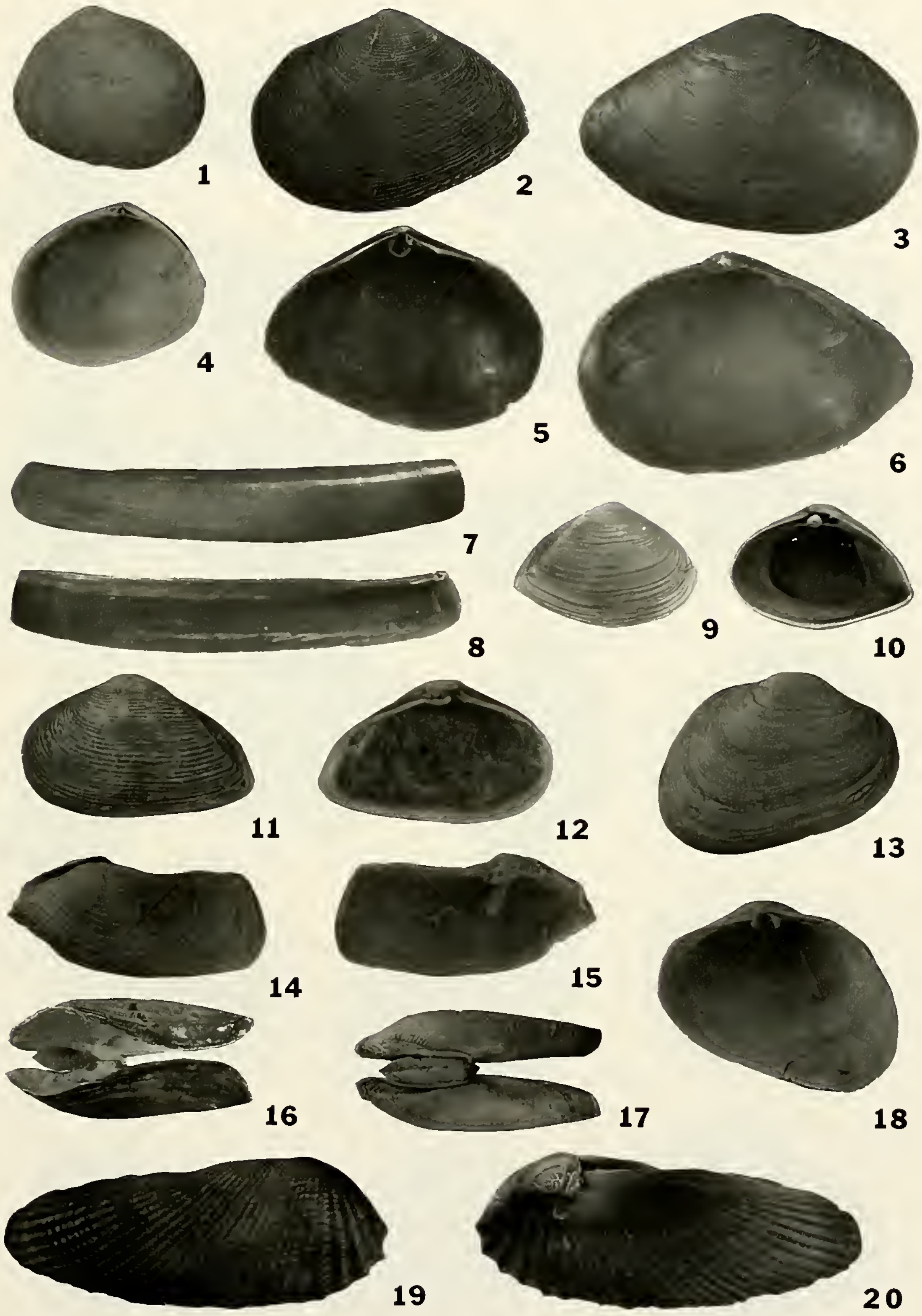
9, 10. ***Corbula swiftiana*** Adams 53
- 9. Right valve, exterior, ×4.2.
- 10. Right valve, interior, ×4.2.
- Locality 18e, Great Bridge Member.
- Hypotype: USNM 218216.

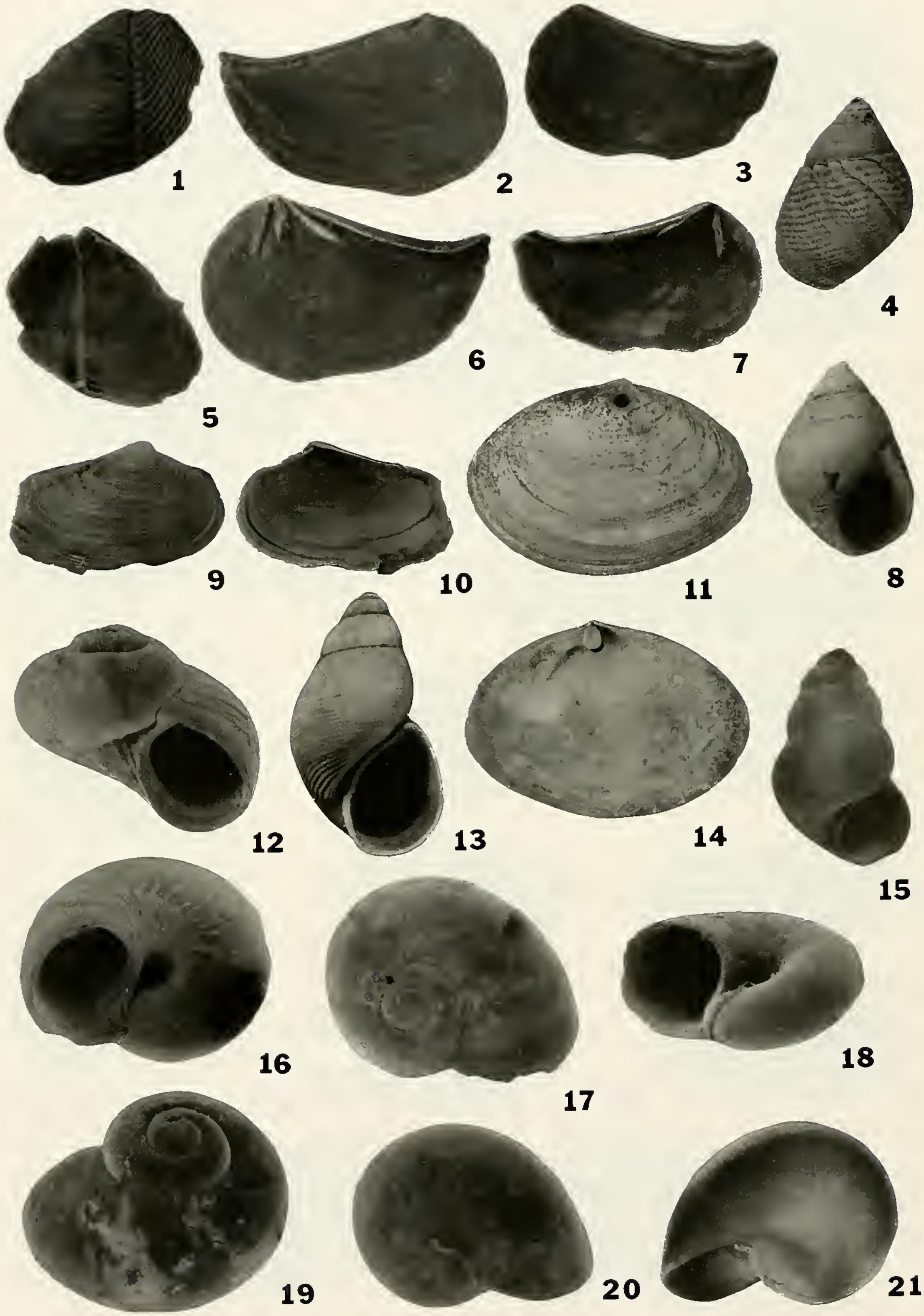
11, 12. ***Corbula contracta*** Say 53
- 11. Left valve, exterior, ×3.5.
- 12. Left valve, interior, ×3.5.
- Locality 17d, Norfolk Member.
- Hypotype: USNM 218215.

13, 18. ***Paramya subovata*** (Conrad) 53
- 13. Right valve, exterior, ×3.
- 18. Right valve, interior, ×3.
- Locality 18d, Norfolk Member.
- Hypotype: USNM 218217.

14–17. ***Barnea truncata*** (Say) 54
- 14. Left valve, exterior, ×0.75.
- 15. Left valve, interior, ×0.75.
- Locality 17c, Kempsville Member.
- Hypotype: USNM 218218.
- 16, 17. Opposed valves (ventral and dorsal views) with protoplax in place, ×0.75.
- Locality 17c, Kempsville Member.
- Hypotype: USNM 218219.

19, 20. ***Cyrtopleura costata*** (Linné) 54
- 19. Right valve, exterior, ×0.5.
- 20. Right valve, interior, ×0.5.
- Locality 17e, Great Bridge Member.
- Hypotype: USNM 218220.

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Explanation of Plate 10

Figure	Page

1, 5. ***Martesia cuneiformis*** (Say) 54
1. Right valve, exterior, ×3.
5. Right valve, interior, ×3.
Locality 18b, Sand Bridge Member.
Hypotype: USNM 409330.

2, 6. ***Pandora gouldiana*** Dall 55
2. Right valve, exterior, ×2.
6. Right valve, interior, ×2.
Locality 18b, Sand Bridge Member.
Hypotype: USNM 218221.

3, 7. ***Pandora trilineata*** Say 55
3. Left valve, exterior, ×2.
7. Left valve, interior, ×2.
Locality 18d, Norfolk Member.
Hypotype: USNM 218222.

4, 8. ***Littorina irrorata*** (Say) 56
×1.5, Locality 17f, Great Bridge Member.
Hypotype: USNM 218227.

9, 10. ***Lyonsia hyalina*** (Conrad) 54
9. Right valve, exterior, ×3.
10. Right valve, interior, ×3.
Locality 17c, Kempsville Member.
Hypotype: USNM 218223.

11, 14. ***Periploma leana*** (Conrad) 55
11. Left valve, exterior, ×2.
14. Left valve, interior, ×2.
Locality 18b, Sand Bridge Member.
Hypotype: USNM 218224.

12, 16, 19. ***Skenea*** species 55
×45, Locality 20b, Norfolk Member.
Hypotype: USNM 218226.

13. ***Cingula norfolkensis***, new species 56
×25, Locality 20b, Norfolk Member.
Holotype: USNM 409331.

15. ***Hydrobia totteni*** Morrison 56
×11, Locality 17b, Kempsville Member.
Hypotype: USNM 218228.

17, 18. ***Vitrinella floridana*** Pilsbry and McGinty 56
×50, Locality 20b, Norfolk Member.
Hypotype: USNM 218229.

20, 21. ***Teinostoma cryptospira*** (Verrill) 57
×40, Locality 20b, Norfolk Member.
Hypotype: USNM 218230.

EXPLANATION OF PLATE 11

Figure — Page

1, 4. ***Circulus liratus*** (Verrill) ... 57
×20, Locality 19, Sand Bridge Member.
Hypotype: USNM 218231.

2, 5. ***Cyclostremiscus jeannae*** Pilsbry and McGinty ... 57
×25, Locality 20b, Norfolk Member.
Hypotype: USNM 218232.

3, 6, 7. ***Solariorbis infracarinata*** (Gabb) ... 57
×30, Locality 20b, Norfolk Member.
Hypotype: USNM 218233.

8, 9, 17. ***Solariorbis*** cf. ***S. blakei*** Rehder ... 57
×50, Locality 20b, Norfolk Member.
Hypotype: USNM 218234.

10. ***Caecum cooperi*** Smith ... 58
×12, Locality 18a, Sand Bridge Member.
Hypotype: USNM 218235.

11–13. ***Caecum johnsoni*** Winkley ... 58
11. ×20, adult. Locality 20b, Norfolk Member.
Hypotype: USNM 218236.
12. ×20, juvenile stage. Locality 20b, Norfolk Member.
Hypotype: USNM 218237.
13. ×20, juvenile stage. Locality 20b, Norfolk Member.
Hypotype: USNM 218238.

14, 15. ***Seila adamsii*** (Lea) ... 59
×7, Locality 17c, Kempsville Member.
Hypotype: USNM 218241.

16. ***Cerithiopsis emersoni*** (Adams) ... 58
×22.5, Locality 20b, Norfolk Member.
Hypotype: USNM 218240.

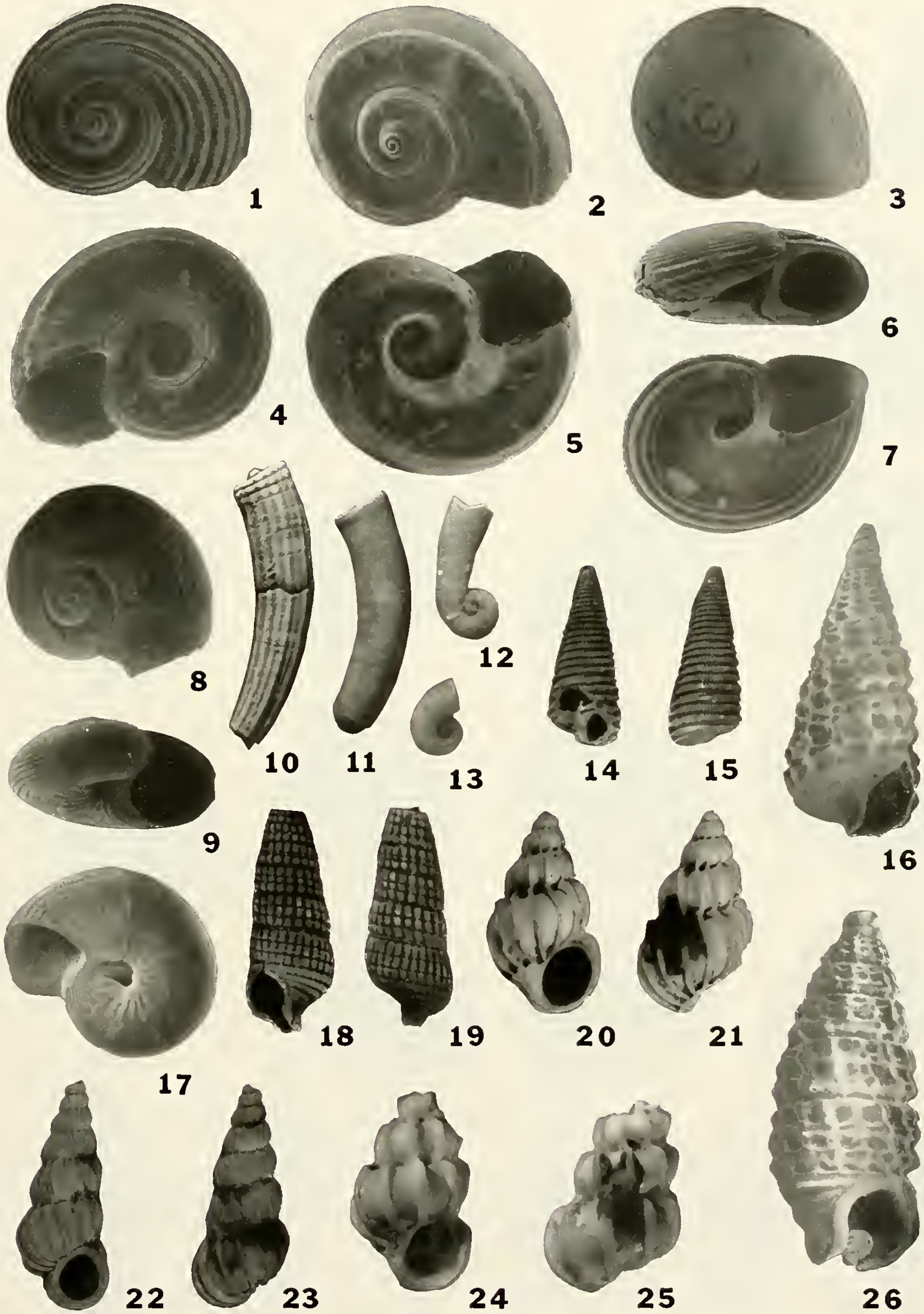
18, 19. ***Triphora nigrocinta*** (Adams) ... 59
×7.5, Locality 17f, Great Bridge Member.
Hypotype: USNM 218242.

20, 21. ***Epitonium angulatum*** (Say) ... 59
×3, Locality 18b, Sand Bridge Member.
Hypotype: USNM 218243.

22, 23. ***Epitonium championi*** Clench and Turner ... 59
×3, Locality 17c, Kempsville Member.
Hypotype: ANSP 64322.

24, 25. ***Epitonium humphreysii*** (Kiener) ... 60
×5, Locality 17c, Kempsville Member.
Hypotype: USNM 218245.

26. ***Cerithiopsis greeni*** (Adams) ... 59
×22.5, Locality 27, Kempsville Member.
Hypotype: USNM 218239.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5.	***Melanella conoidea*** (Kurtz and Stimpson) ×10.5, Locality 17c, Kempsville Member. Hypotype: USNM 218248.	60
6.	***Melanella intermedia*** (Cantraine) ×6, Locality 18d, Norfolk Member. Hypotype: USNM 218244.	61
7, 12.	***Crepidula convexa*** Say ×3, Locality 17c, Kempsville Member. Hypotype: USNM 218249.	61
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10, 11.	***Crepidula plana*** Say ×1, Locality 17c, Kempsville Member. Hypotype: USNM 218251.	61
13.	***Crucibulum striatum*** (Say) ×1.5, Locality 17b, Kempsville Member. Hypotype: USNM 218252.	61
14, 18.	***Polinices duplicatus*** (Say) ×0.75, Locality 17c, Kempsville Member. Hypotype: USNM 218253.	62
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22, 23.	***Sinum perspectivum*** (Say) ×1.2, Locality 22a, Norfolk Member. Hypotype: USNM 218257.	62
24, 25.	***Boreotrophon tetricus*** (Conrad) ×2, Yorktown Formation (Pliocene), *Panopea* Bed, Chuckatuck, VA. Hypotype: USNM 218258.	64
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	1, 2. ×1.5, Locality 17d, Norfolk Member. Hypotype: USNM 218261.	
	3, 4. ×1.5, malformed with varices. Locality 17d, Norfolk Member. Hypotype: USNM 218262.	
5, 10.	***Thais haemastoma floridana*** (Conrad) ×0.75, Locality 17f, Great Bridge Member. Hypotype: USNM 218263.	63
6, 7.	***Buccinum undatum undatum*** Linné ×1, Locality 17b, Kempsville Member. Hypotype: USNM 218264.	65
8, 9, 13, 14.	***Atractodon stonei*** (Pilsbry)	65
	8, 9. ×6, juvenile. Locality 23, Kempsville Member. Hypotype: USNM 218265.	
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15, 16.	***Cantharus cancellarius*** (Conrad) ×1.2, Locality 17f, Great Bridge Member. Hypotype: USNM 218268.	65
17, 18.	***Anachis lafresnayi*** (Fischer and Bernardi) ×3, Locality 17c, Kempsville Member. Hypotype: USNM 218269.	64
19, 20.	***Anachis obesa*** (Adams) ×9, Locality 17f, Great Bridge Member. Hypotype: USNM 218270.	64


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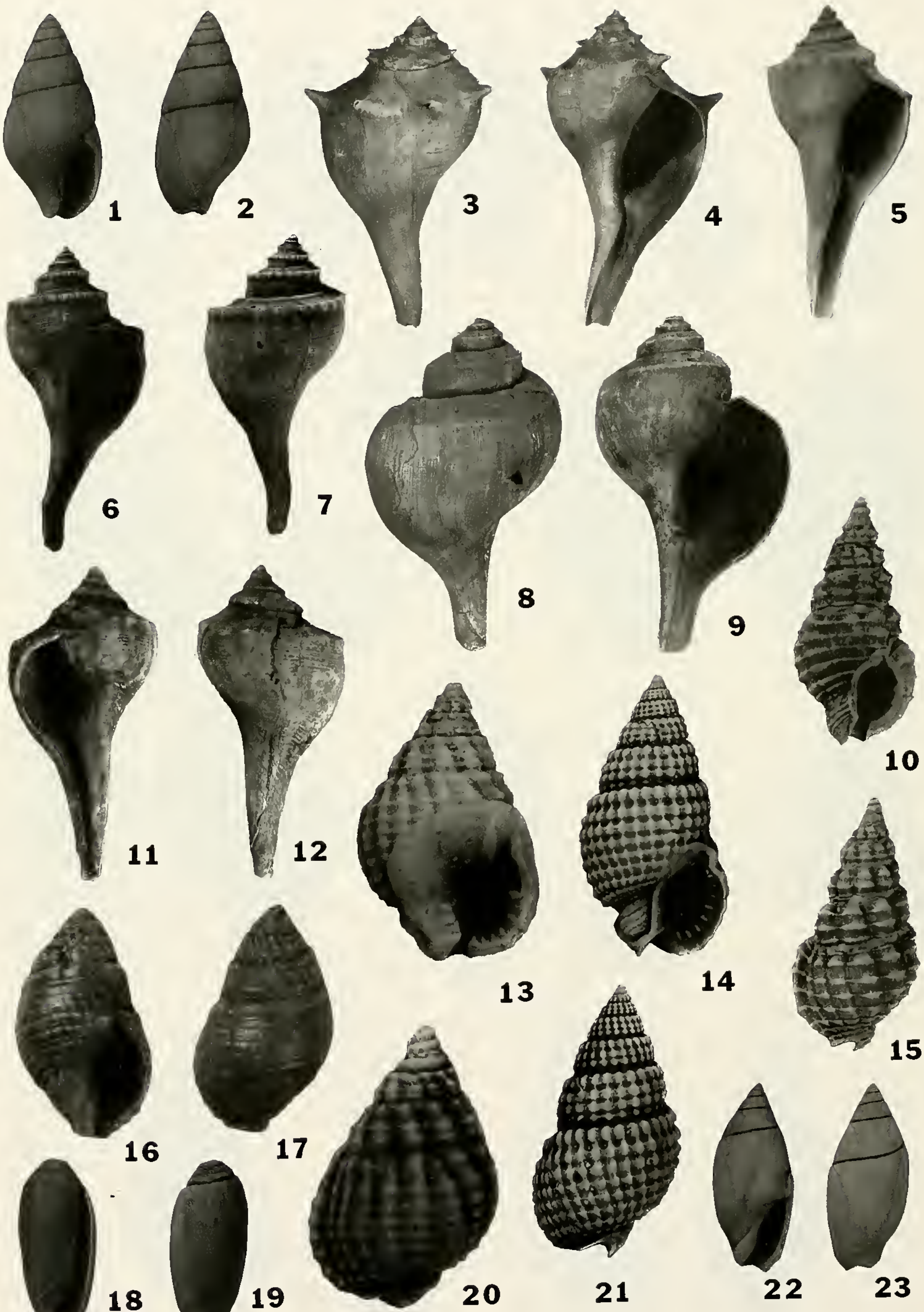
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Explanation of Plate 14

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1, 2. ***Mitrella lunata*** (Say) 64
×6, Locality 17c, Kempsville Member.
Hypotype: USNM 218271.

3–5. ***Busycon carica*** (Gmelin) 66
3, 4. ×0.37, adult. Locality 17e, Norfolk Member.
Hypotype: USNM 218272.
5. ×0.81, juvenile. Locality 17e, Norfolk Member.
Hypotype: USNM 218273.

6–9. ***Busycon canaliculatum*** (Linné) 66
6, 7. ×0.75, juvenile. Locality 17b, Kempsville Member.
Hypotype: USNM 218274.
8, 9. ×0.25, adult. Locality 17b, Kempsville Member.
Hypotype: USNM 218275.

11, 12. ***Busycon contrarium*** (Conrad) 66
×1.4, Locality 17d, Norfolk Member.
Hypotype: USNM 218276.

10, 15. ***Nassarius acutus*** (Say) 67
×4, Locality 17f, Great Bridge Member.
Hypotype: USNM 218277.

13, 20. ***Nassarius vibex*** (Say) 67
×3, Locality 17e, Norfolk Member.
Hypotype: USNM 218278.

14, 21. ***Nassarius (Hinia) trivittatus*** (Say) 67
×2, Locality 17c, Kempsville Member.
Hypotype: USNM 218280.

16, 17. ***Nassarius (Ilyanassa) obsoletus*** (Say) 67
×2, Locality 17d, Norfolk Member.
Hypotype: USNM 218279.

18, 19. ***Oliva sayana*** Ravenel 67
×1.2, Locality 17c, Kempsville Member.
Hypotype: USNM 218281.

22, 23. ***Olivella mutica*** (Say) 68
×1.5, Locality 17c, Kempsville Member.
Hypotype: USNM 218282.

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1, 2. ***Dentimargo aureocincta*** (Stearns) 68
×6, Locality 17c, Kempsville Member.
Hypotype: USNM 218283.

3, 4. ***Prunum roscidum*** (Redfield) 68
×2, Locality 17d, Norfolk Member.
Hypotype: USNM 218284.

5, 6. ***Granulina ovuliformis*** (d'Orbigny) 68
×13.5, Locality 17d, Norfolk Member.
Hypotype: USNM 218285.

7, 8. ***Terebra concava*** (Say) 69
×2, Locality 18b, Sand Bridge Member.
Hypotype: USNM 218286.

9, 25. ***Terebra dislocata*** (Say) 69
×2, Locality 18d, Norfolk Member.
Hypotype: USNM 218287.

10, 11. ***Kurtziella cerina*** (Kurtz and Stimpson) 69
×8, Locality 19, Sand Bridge Member.
Hypotype: USNM 218288.

12, 13. ***Brachycythara galae dimonia*** Fargo 69
×4, Locality 19, Sand Bridge Member.
Hypotype: USNM 218289.

14, 15. ***Lonchaeus arenosa*** (Conrad) 70
×3.5, Locality 17d, Norfolk Member.
Hypotype: USNM 218290.

16. ***Eulimastoma*** cf. ***E. weberi*** (Morrison) 70
×10.5, Locality 22b, Norfolk Member.
Hypotype: USNM 218291.

17, 18. ***Turbonilla interrupta*** (Totten) 71
×5, Locality 17c, Kempsville Member.
Hypotype: USNM 218292.

19. ***Turbonilla reticulata*** (Adams) 71
×11.8, Locality 20b, Norfolk Member.
Hypotype: USNM 218293.

20. ***Odostomia gibbosa*** Bush 70
×10.8, locality 19, Sand Bridge Member.
Hypotype: USNM 218294.

21, 22. ***Odostomia impressa*** (Say) 71
×7.5, Locality 20b, Norfolk Member.
Hypotype: USNM 218295.

23, 24. ***Odostomia seminuda*** (Adams) 71
×6, Locality 17d, Norfolk Member.
Hypotype: USNM 218296.

26. ***Odostomia dianthophila*** Wells and Wells 70
×28, Locality 20b, Norfolk Member.
Hypotype: USNM 218297.

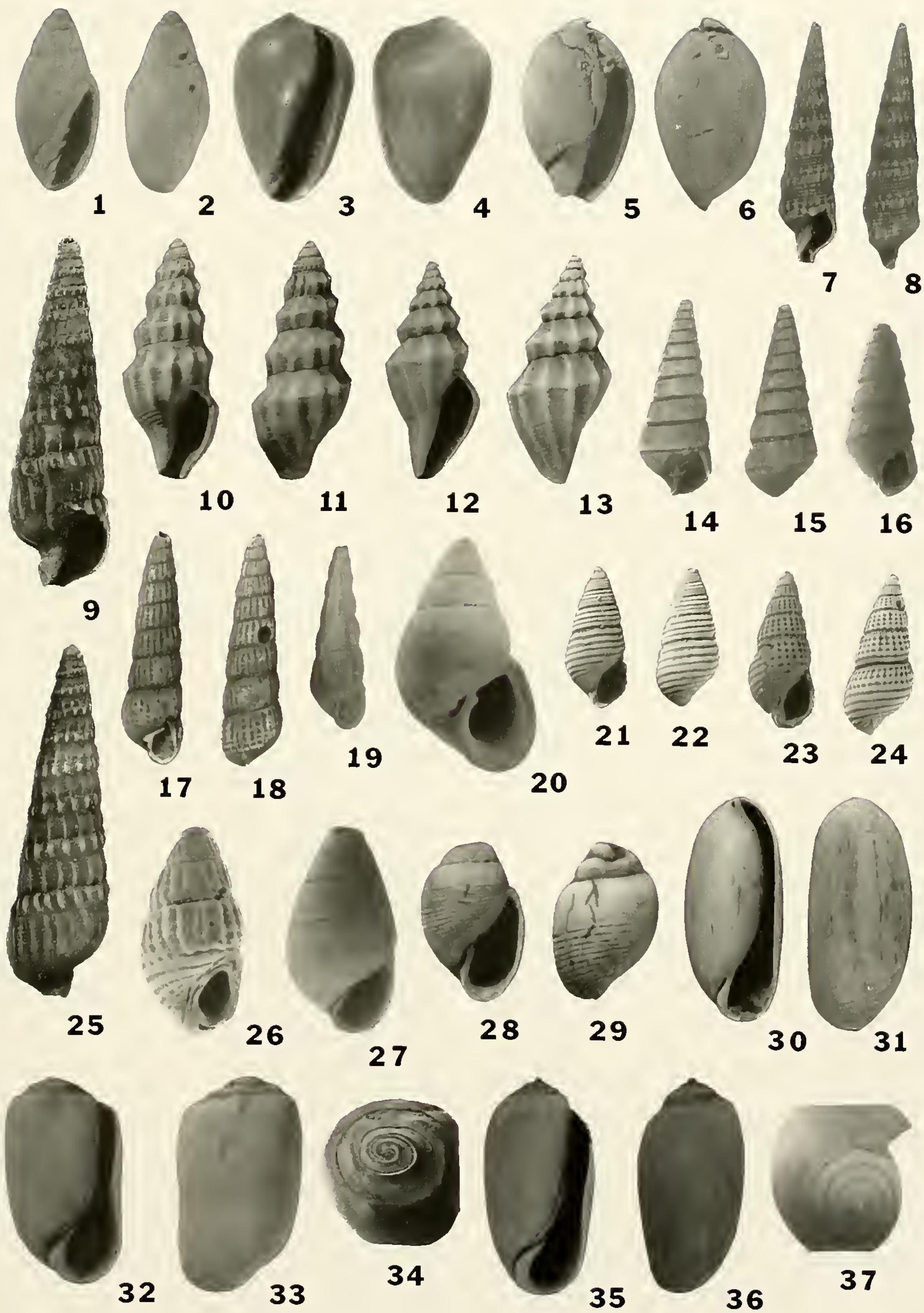
27. ***Odostomia (Sayella) fusca*** (Adams) 70
×30, Locality 20b, Norfolk Member.
Hypotype: USNM 218298.

28, 29. ***Rictaxis punctostriatus*** (Adams) 72
×25, Locality 20b, Norfolk Member.
Hypotype: USNM 218299.

30, 31. ***Volvulella aspinosa*** (Dall) 72
×4.2, Locality 17d, Norfolk Member.
Hypotype: USNM 218300.

32–34. ***Retusa obtusa*** (Montagu) 72
32, 33. ×9, Locality 20b, Norfolk Member.
34. ×12.5, apical view, Locality 20b, Norfolk Member.
Hypotype: USNM 218301.

35–37. ***Acteocina canaliculata*** (Say) 72
35, 36. ×9, Locality 17d, Norfolk Member.
37. ×12.5, apical view, Locality 17d, Norfolk Member.
Hypotype: USNM 218302.



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FORMATION	RECENT				POWELLS CROSSROADS					ACREDALE																			
Member	Boreal	N. Virginian	S. Virginian	Carolinian Caribbean	Sand Bridge				London-Bridge	Kempsville					Norfolk												Great Bridge		
					Upper		Lower			Upper			Lower		Upper										Lower				
Sample Number					19a	18a	20a	18b	18c	23	17b	17a	22a	17c	30	29	28	27	26a	25a	22b	21a	18d	17d	20b	17e	22c	18e	17f
MOLLUSCA GASTROPODA																													
Acteocina canaliculata	X	X	X	X	A	C	-	C	-	-	A	-	A	C	-	X	-	-	A	C	A	C	A	A	-	A	-	C	A
Anachis avara	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anachis lafresnayi	X	X	X	X	-	-	-	-	-	-	-	-	-	S	-	-	-	-	S	S	S	-	-	R	-	-	-	R	-
Anachis obesa	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	C	C
Atractodon stonei	X	X	X	X	S	C	-	C	-	S	S	-	S	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bracycythara galae dimonia	X	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Buccinum undatum undatum	-	X	X	X	-	-	-	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Busycon canaliculatum	X	X	X	-	S	S	-	S	S	-	C	-	S	S	-	-	X	X	S	S	-	C	S	R	-	-	-	-	-
Busycon carica	X	X	X	-	-	C	-	S	C	-	C	-	C	S	-	-	S	X	C	S	-	A	C	R	R	C	-	-	-
Busycon carica eliceans	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Busycon contrarium	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-
Caecum cooperi	X	X	X	-	-	A	-	-	-	-	C	-	-	-	-	-	-	-	C	-	-	-	-	-	C	-	-	-	-
Caecum johnsoni	X	X	X	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-
Cantharus cancellarius	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	S	S
Cerithiopsis emersoni	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Cerithiopsis greeni	X	X	X	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	S	-	-	-	-	R	S	S	-	-	A
Cingula norfolkensis	X	X	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
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Colus pygmaeus	-	X	X	X	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Crepidula convexa	X	X	X	-	A	-	-	C	-	-	S	-	C	A	-	-	X	-	C	C	C	-	C	C	S	-	-	-	-
Crepidula fornicata	X	X	X	X	-	S	X	S	S	-	C	-	S	S	-	-	-	-	R	-	S	S	-	-	-	-	-	S	R
Crepidula plana	X	X	X	X	C	C	X	C	C	-	C	-	C	C	-	-	-	-	C	C	C	-	C	A	S	A	-	C	S
Crucibulum striatum	X	X	X	X	-	-	-	-	-	-	S	-	R	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyclostremiscus jeannae	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-
Dentimargo aureocincta	X	X	-	-	-	-	-	R	-	-	S	-	-	R	-	-	-	-	R	-	-	-	R	-	-	-	-	-	-
Olastoma alternatum	-	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-
Epitonium angulatum	X	X	X	-	-	-	-	C	-	-	-	-	-	S	-	-	-	-	R	-	-	-	C	S	-	-	-	C	S
Epitonium championi	X	X	X	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epitonium humphreysii	X	X	X	-	S	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-
Epitonium multistriatum	X	X	X	-	-	-	-	S	-	-	-	-	-	S	-	-	-	-	S	-	-	-	-	S	R	-	-	S	C
Epitonium rupicolum	X	X	X	-	-	-	-	S	-	-	-	-	-	-	-	X	-	-	S	-	-	-	S	S	R	-	-	C	S
Eulimastoma cf. E. weberi	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-
Eupleura caudata	X	X	X	-	C	S	X	S	-	-	R	-	S	A	-	-	X	X	C	C	A	C	S	C	A	S	-	-	A
Granulina ovuliformis	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-
Hydrobia totteni	-	-	X	X	-	-	-	-	-	-	-	-	-	R	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-
Kurtziella cerina	X	X	X	-	S	-	-	C	-	-	S	-	-	S	-	-	-	-	C	-	-	S	C	-	S	-	-	S	-
Littorina irrorata	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S
Longchaeus crenusa	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	R	-	-	R	-	-	-	-	-
Lunatia heros	-	X	X	X	-	C	-	C	C	A	C	-	C	S	-	-	-	-	S	-	-	C	C	R	-	-	-	-	-
Lunatia triseriata	-	X	X	X	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Melanella conoidea	X	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Melanella intermedia	X	X	-	-	S	-	-	-	-	-	-	-	-	R	-	-	-	-	R	-	-	-	-	R	-	-	-	-	R
Mitrella lunata	X	X	X	-	S	C	X	C	-	-	A	-	C	A	-	-	-	-	A	C	C	-	C	A	R	S	-	C	S
Nassarius acutus	X	X	-	-	C	-	-	R	-	-	-	-	-	S	-	-	-	-	S	-	-	-	R	R	A	S	-	C	A
Nassarius (Ilyanassa) obsoletus	X	X	X	X	-	S	-	-	-	-	R	-	S	A	-	-	X	-	C	C	C	C	-	C	C	S	-	S	A
Nassarius (Hinia) trivittatus	-	X	X	X	S	C	X	C	-	A	C	-	S	C	-	X	X	X	C	C	C	C	C	A	R	-	-	-	-
Nassarius vibex	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	R	-	-	-	R	A	C	-	A	A
Odostomia (Sayella) fusca	X	X	X	X	S	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-
Odostomia dianthophila	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-
Odostomia gibbosa	-	X	X	X	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	S	-	-	-	-	-
Odostomia impressa	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	R	C	S	-	C	A
Odostomia seminuda	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	S	-	S	-	C	S
Oliva sayana	X	X	-	-	-	-	-	R	-	R	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Olivella mutica	X	X	-	-	A	C	X	-	C	-	C	-	S	A	-	-	-	X	A	C	C	C	A	C	S	-	-	S	-
Polinices duplicatus	X	X	X	-	C	C	X	C	C	-	C	-	C	A	X	-	X	X	C	C	S	A	C	S	A	A	-	C	C
Prunum roscidum	X	X	X	-	S	S	X	-	-	-	S	-	-	C	-	-	-	X	C	C	C	S	C	A	-	-	-	-	-
Retusa obtusa	-	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-
Rictaxis punctostriatus	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	S	A
Seila adamsii	X	X	X	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	R	-	-	-	-	R	-	-	-	-	R
Sinum perspectivum	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-
Skenea sp.	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-
Solariorbis infracarinata	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Solariorbis cf. S. blakei	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-
Tectonatica pusilla	X	X	X	X	C	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Teinostoma cryptospira	X	X	-	-	-	-	-	-	-	-	S	-	-	S	-	-	-	-	-	-	-	-	-	S	C	-	-	-	-
Terebra concava	X	X	-	-	S	C	-	C	S	-	R	-	-	S	-	-	-	-	S	-	-	-	C	-	S	-	-	S	R
Terebra dislocata	X	X	-	-	S	S	X	A	-	-	R	-	-	S	-	-	-	-	S	-	-	-	C	-	-	R	-	S	-
Thais haemastoma floridana	X	X	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	S	-	C	C
Triphora nigrocincta	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	C	-	-	-	S	-	S	-	-	C
Turbonilla interrupta	X	X	X	X	A	-	-	A	-	-	S	-	C	C	-	-	-	-	C	C	A	-	A	C	C	C	-	A	A
Turbonilla puncta	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbonilla reticulata	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-
Urosalpinx cinerea	X	X	X	X	-	S	-	-	-	-	R	-	S	A	-	-	-	-	C	C	C	-	-	C	-	S	-	R	R
Vitrinella floridana	X	X	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Volvulella aspinosa	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-
ARTHROPODA MACRO-CRUSTACEA																													
Amphipod species	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arenaeus cribrarius	X	X	X	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Balanus eburneus	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-
Balanus improvisus	X	X	-	-	-	S	-	C	-	-	C	-	C	C	-	-	-	-	C	C	C	-	C	R	-	C	-	C	C
Callianassa atlantica	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	C	C	-	R	C	-	-	-	-	-
Callinectes sapidus	X	X	X	X	-	-	-	R	-	-	-	-	-	R	-	-	-	-	S	S	S	-	-	R	-	-	-	-	-
Cancer irroratus	X	X	X	X	-	R	-	-	-	-	S	-	R	S	-	-	-	-	S	C	R	-	R	S	-	-	-	-	-
Coronis ruber	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	R	-	-	-	-	-
Homarus americanus	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-
Libinia dubia	X	X	X	-	-	-	-	-	-	-	S	-	C	S	-	-	-	-	S	C	C	-	-	-	-	-	-	-	-
Libinia emarginata	X	X	X	X	-	-	-	-	-	-	R	-	S	S	-	-	-	-	S	C	C	-	R	R	-	-	-	-	-
Menippe mercenaria	X	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	S	C	C	-	-	S	-	-	-	-	-
Neopanope texana sayi	X	X	X	X	-	-	-	-	-	-	S	-	C	S	-	-	-	-	C	A	A	-	R	C	-	-	-	-	-
Ocypode sp.	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ovalipes ocellatus	X	X	X	X	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	C	-	-	-	-	-	-	-	-
Pagurus pollitus	-	X	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	S	-	-	S	-	-	-	-	-
Panopeus herbstii	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-
Persephona sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-
Squilla empusa	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-
ARTHROPODA OSTRACODA																													
Actinocythereis dawsoni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-
Actinocythereis aff. A. gomillionensis	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Aurila floridana	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Bensonocythere americana	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	-	X	X	-	-	-	-	-
Bensonocythere arenicola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	X	X	-	-	-	-	-
Bensonocythere sapeloensis	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Bensonocythere cf. B. sapeloensis	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Bensonocythere whitei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	X	X	-	-	-	-	-
Bensonocythere sp. A	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Bensonocythere sp. B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Bensonocythere sp. D	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	-	X	X	-	-	-	-	-
Bensonocythere sp. E	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Bensonocythere sp. G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
Camplocythere laeva	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Cushmanidea magniporosa	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	-	X	X	X	X	-	-	-	-	-
Cushmanidea seminuda	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	-	X	X	X	X	-	-	-	-	-
Cushmanidea sp. B	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Cushmanidea sp. C	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	-	-	X	-	-	-	-	-	-	-
Cyprideis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X	-	-	-	-	-	-
Cytheridea sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	X	-	-	-	-	-	-
Cytheromorpha warneri newportensis	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	X	X	-	-	X	-	-	-	-	-
Cytheromorpha sp. A.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	X	X	-	-	-	-	-	-
Cytheropteron pyramidale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Cytherura forulata	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Cytherura howei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Cytherura pseudostriata	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	X	-	X	X	-	-	-	-	-
Cytherura reticulata	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Cytherura wardensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	-	X	-	-	-	-	-
Cytherura sp. A	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	-	X	-	-	-	-	-
Cytherura sp. B	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	-	X	-	-	-	-	-
Cytherura sp. D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	-	X	-	-	-	-	-
Cytherura sp. E	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-
Eucythere declivis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	X	-	-	-	-	-
Eucythere gibba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Finmarchinella finmarchica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	-	-	-	-	-
Haplocytheridea bradyi	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Haplocytheridea setipunctata	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Hemicythere villosa	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Hulingsina americana	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Hulingsina glabra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-
Hulingsina rugipustulosa	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Hulingsina sp. A	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Hulingsina sp. B	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Hulingsina sp. C	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-
Hulingsina sp. D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X	-	-	-	-	-	-
Leptocythere angusta	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	-	-	X	-	-	-	-	-
Leptocythere cf. L. nikraveshae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-
Leptocythere sp. A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-
Loxoconcha aff. L. granulata	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	X	X	X	X	X	-	-	-	-	-
Loxoconcha matagordensis	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Loxoconcha sperata	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	-	X	-	-	X	-	-	-	-	-
Megacythere stephensoni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-
Megacythere sp. B	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	X	X	X	X	X	-	-	-	-	-
Microcytherura choctawhatcheensis	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	X	X	X	X	X	-	-	-	-	-
Microcytherura sp. A	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Microcytherura sp. B	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	X	X	-	X	-	-	-	-	-
Microcytherura sp. C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	X	X	-	-	-	-	-
Muellerina canadensis	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Muellerina aff. M. lienenklausi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-
Neocaudites sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	-	X	-	-	X	-	-	-	-	-
Neolophocythere subquadrata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	-	-	-	-	-	-	-
Neolophocythere sp. A	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Paracytheridea altila	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-
Paracytheridea sp. A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-	-	-	-
Paradoxostoma delicata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	X	-	-	-	-	-
Paradoxostoma sp. B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
Paradoxostoma sp. C	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-
Paradoxostoma sp. F	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	-	-	X	-	-	-	-	-
Pellucistoma magniventra	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	-	X	-	-	X	-	-	-	-	-
Propontocypris edwardsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	X	X	-	-	-	-	-
Proteoconcha gigantica	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Proteoconcha nelsonensis	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Proteoconcha tuberculata	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X	-	X	X	X	-	-	-	-	-
Protocytheretta aff. P. sahnii	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	X	X	X	X	-	-	-	-	-
Pseudocytheretta edwardsii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
Puriana floridana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	X	X	X	-	-	-	-	-
Puriana rugipunctata	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	-	-	-	X	X	-	-	-	-	-
"Sahnia" sp. A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	X	X	X	-	-	-	-	-
"Sahnia" sp. B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	X	X	-	-	-	-	-
Sclerochilus sp. C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	-	-	-	-	-
Sclerochilus sp. D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-
ECHINODERMATA																													
Arbacia punctualta	X	X	X	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-
Echinarachinus parma	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-
Mellita quinquesperforata	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-
VERTEBRATA PISCES																													
Astroscopus sp.	-	X	X	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brevoortia sp.	X	X	X	X	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carcharias sp.	X	X	X	X	-	-	-	-	-	-	R	-	-	R	-	-	-	-	-	-	-	-	R	-	-	-	-	R	-
Carcharinus sp.	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	R	-	-	-	-	-	-
Cynoscion sp.	X	X	X	X	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dasyatis sp.	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	R
Gadus sp.	-	X	X	X	-	-	-	-	-	-	R	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lophius sp.	-	X	X	X	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lutianus sp.	X	X	X	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Micropogon undulatus	X	X	X	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Myliobatis sp.	X	X	X	-	-	-	-	R	-	-	R	-	-	R	-	-	-	-	-	-	-	-	R	-	-	-	-	R	R
Opsanus sp.	X	X	X	X	-	-	-	-	-	-	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pogonias sp.	X	X	X	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prionotus sp.	X	X	X	-	-	-	-	-	-	-	R	-	-	S	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-
Raja sp.	X	X	X	X	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-
Sciaenops sp.	X	X	X	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphyraena sp.	X	X	X	-	-	-	-	-	-	-	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VERTEBRATA AVES																													
Branta bernicla	-	X	X	X	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Larus hyperboreus	X	X	X	X	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Morus bassanus	-	X	X	X	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phalacrocorax auritus	X	X	X	X	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pinguinus impennis	-	-	X	X	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Podiceps auritus	-	X	X	X	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Uria aalge	X	X	X	X	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VERTEBRATA MAMMALIA																													
Halichoerus grypus	-	X	X	X	-	-	-	-	-	-	S	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mastodon americanus	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mysticete rib	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Odobenus rosmarus	-	X	X	X	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
porpoise tooth	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-

PREPARATION OF MANUSCRIPTS

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Collinson, J.
1962. *Size of lettering for text-figures.* Journal of Paleontology, vol. 36, p. 1402.

Gilbert Dennison Harris
(1864 - 1952)

Founder of the *Bulletins of American Paleontology* (1895)

ISBN 0-87710-407-7