

TAPHONOMIC CHARACTERISTICS OF OFFSHORE MOLLUSK SHELLS,  
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## I. ABSTRACT

Detrital mollusk valves from a small area on the offshore (palimpsest) shelf near Sapelo Island were analyzed with respect to (1) proportions of new and old shells, (2) degree of encrustation or boring by subsequent organisms, and (3) general provenance of shell assemblages. Old shells predominated at both landward and seaward sites, whereas new shells predominated at intermediate sites; many new and most old shells were invested with encrustings (mainly bryozoans, serpulids) and/or borings (mainly sponges, barnacles). Valves of nearshore species were most abundant at landward sites, but valves of offshore species were somewhat more evenly distributed. These observations suggest that (1)

nearshore and offshore components remain essentially in-situ, (2) old shells tend to be more intensely bored or encrusted than new shells, (3) proportions of old and new shells, and bored or encrusted shells, are governed principally by the duration of their exposure to physical and biological processes at the sediment-water interface, which is enhanced by extremely slow rates of deposition in this area, but that (4) such conclusions must be based upon the character of the total assemblage, not the condition of individual shells.

## II. INTRODUCTION

The carbonate fractions of Atlantic beach and continental shelf sediments have been the object of numerous mineralogic and sedimentologic investigations (e.g., Pilkey *et al.*, 1967, 1968; Frey and Pinet, 1978). Of particular interest to

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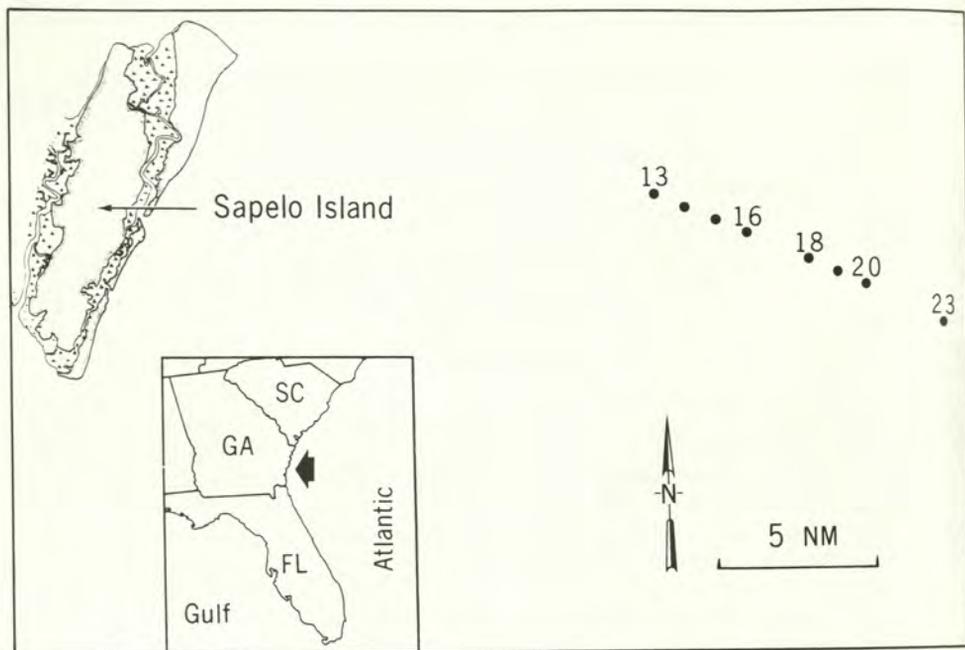


Fig. 1. Index map of study area, Sapelo Island, Georgia. Station designations refer to the number of nautical miles offshore.

both sedimentologists and paleontologists is the condition of skeletal allochems as an approximate indicator of environmental processes and depositional history (Pilkey *et al.*, 1979). Among the more important parameters of mollusk shell condition are degrees of abrasion, fragmentation, and rounding, proportions of fresh and old shells, amount of shell staining or discoloration, and intensity of boring or encrustation by other organisms (Pilkey *et al.*, 1969a, 1969b).

Most studies cited above refer to regional aspects of these carbonate fractions and their broad implications. The present report, in contrast, is concerned chiefly with conditions of mollusk shells on a small segment of the shelf off Sapelo Island, Georgia (Fig. 1). Major objectives included (1) differentiation of new and old shell components within the total assemblage, (2) characterization of shell encrustation and boring by other organisms, (3) evaluation of nearshore and offshore species distributions, and (4) reconstruction of physical and biological aspects of shell provenance.

Despite limitations of the data set (Appendix) this analysis of local assemblages should help augment or clarify many of the shell parameters outlined previously, particularly as they relate to local fossil accumulations typically encountered by paleontologists (Fürsich, 1978; Kidwell, 1982; Kidwell and Jablonski, 1983).

### III. METHODS AND SETTING

Eight stations along a transect off the northern end of Sapelo Island (Fig. 1) were sampled by means of a NEL spade corer (see Smith and Howard, 1972; Howard and Frey, 1975). Each sample consisted of  $\approx 0.015 \text{ m}^3$  of sediment. Shells were recovered by sieving sediments through a 2.5 mm mesh screen; only distinct, readily identifiable shells were retained for analysis, in contrast with the whole-sample analyses by Pilkey (1964) and Pilkey *et al.* (1969b). Individual bivalve valves were tallied as separate specimens, although articulated shells were recorded; these bivalve abundance data, therefore, might be halved with respect to the gastropod

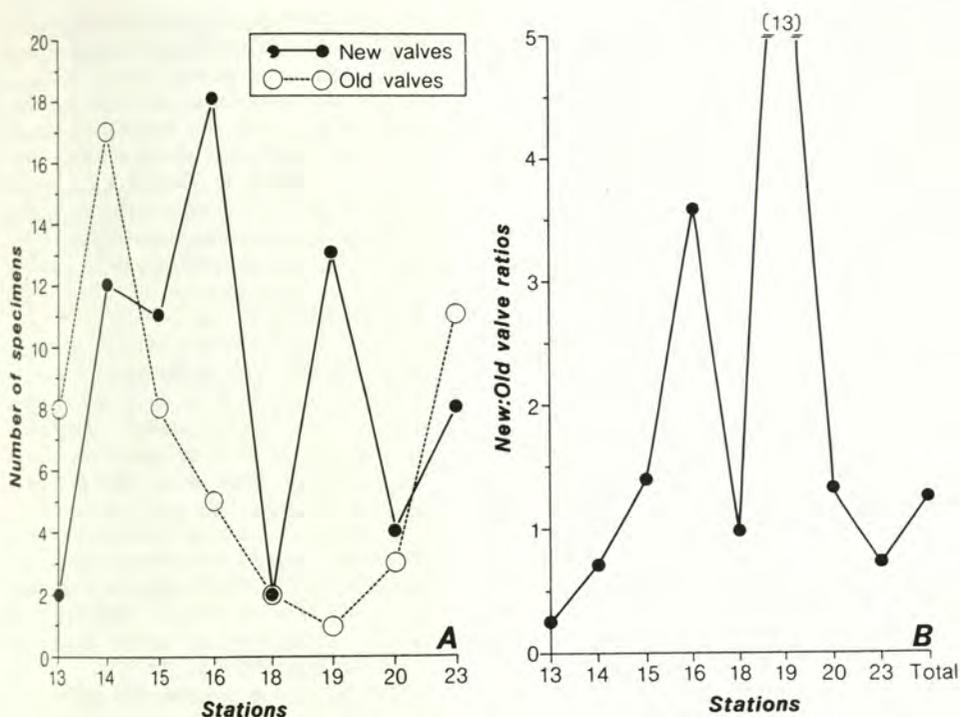


Fig. 2. Relative abundance of detrital mollusk shells. Individual bivalve valves were tallied as separate specimens (see methods). (A) Frequency of new and old valves. (B) Ratio of new to old valves; values greater than 1 = predominance of new valves and values greater than 1 = predominance of old valves.

abundance data. For taxonomic consistency, all species names were adopted from Abbott (1974).

Environmentally, all samples are from the lower offshore zone, albeit slightly seaward of the area described by Howard and Reineck (1972); this area is essentially equivalent to the inner-middle shelf zone discussed by Pilkey *et al.* (1969b) and Howard and Frey (1980). Water depths are on the order of 12 to 15 m. Sediments consist principally of clean, palimpsest (Pleistocene), medium- to coarse-grained, bioturbated sand, inhabited by modern benthic organisms (Dörjes, 1972). Shell assemblages thus exhibit considerable temporal mixing; environmental mixing also resulted from Pleistocene transgressions and regressions across the shelf (Blackwelder *et al.*, 1979). Such mixed assemblages are difficult to decipher because individual species of mollusks remained extant

throughout Quaternary time. [In inlet-channel scours, they also are admixed with Tertiary fossils (Frey *et al.*, 1975).]

#### IV. RESULTS AND DISCUSSION

In these analyses, major emphasis was placed upon identifiable mollusk shells. Less diagnostic fragments were discarded, without regard for their total abundance or distribution. Except for scattered small, thin fragments of echinoid tests, presumably the heart urchin *Moira atropos* (Dörjes, 1972), other skeletal carbonates were comparatively minor macroscopic constituents of the sediment. However, one nearly intact, albeit old, test of the sand dollar *Melita sexiesperforata* was recovered at Station 23 [nearshore sand dollars, in contrast, are referable to *M. quinquesperforata* (cf. Bell and Frey, 1969).]

Relatively few stained or discolored mollusk shells were observed. Of 125 speci-

mens analyzed, three valves of *Mulinia lateralis* were brown, and one valve of *M. lateralis*, one of *Crassostrea virginica*, and two of *Anomia simplex* were black (cf. Pilkey *et al.*, 1969b). Thus, the host substrates apparently remained predominantly within the oxidizing zone during accumulation of the shell assemblages.

Most bivalve shells were disarticulated and scattered; where left and right valves of the same species were present, most were of different sizes. The only exceptions were one articulated specimen of *Linga pensylvanica* and two of *Laevicardium pictum*.

#### New Versus Old Shells

Many workers have noted the contrast between fresh- and old-shell assemblages on the Atlantic shelf (e.g., Pilkey, 1964; Pilkey *et al.*, 1969b). The same is true of the lower offshore zone on the Georgia shelf (Appendix). Of total shells recovered during this study, 56% were classified as new and 44% were classified as old specimens.

Criteria for temporal classifications of shells vary among authors. Recent experience on the Georgia coast (Henderson and

Frey, 1986) suggests that such features as shell breakage, staining, dissolution, and encrustation or boring have inconsistent temporal implications and, therefore, are somewhat unreliable indices of relative age. Instead, fresh shells are best indicated by retention of original color, varnish, or gloss, or organic constituents such as ligament or periostracum; old shells lack these features and also may be bleached or chalky in appearance (cf. Trewin and Welsh, 1972).

All kinds of criteria remain subjective to some extent. Yet, those adopted for the present study seem to work well, on the whole, and were applied consistently throughout the analysis. [Early attempts at  $^{14}\text{C}$  dating (cf. Panin *et al.*, 1983) proved to be prohibitively expensive because of extreme temporal mixing of the assemblages; thorough radiometric analysis would require the systematic dating of numerous shells from each sample, together with careful evaluation of possible diagenetic changes (Ragland *et al.*, 1979).]

By the above criteria, old shells predominated at both the landward and sea-

Table 1. Summary of encrustations and borings invested upon detrital mollusk valves off Sapelo Island.

Investments*	Gastropods		Bivalves		Total	
	New N(%)	Old N(%)	New N(%)	Old N(%)	New N(%)	Old N(%)
<b>ENCrustATIONS:</b>						
bryozoans	3(21)	3(43)	11(20)	31(65)	14(20)	34(62)
serpulids	1 (7)	1(14)	10(18)	27(56)	11(16)	28(51)
bivalve spat	-	1(14)	5 (9)	8(17)	5 (7)	9(16)
barnacles	-	1(14)	-	7(15)	-	8(15)
<b>BORINGS:</b>						
sponges	-	4(57)	1 (2)	17(35)	1 (1)	21(38)
barnacles	1 (7)	1(14)	-	7(15)	1 (1)	8(15)
gastropods	-	-	7(13)	3 (6)	7(10)	3 (5)
gastrochaenids	-	-	3 (5)	3 (6)	3 (4)	3 (5)
algae-fungi	-	-	1 (2)	6(13)	1 (1)	6(11)
Total encrusted valves	4(29)	(43)	17(30)	35(73)	21(30)	38(69)
Total bored valves	1 (7)	4(57)	10(18)	26(54)	11(16)	30(55)
Total invested valves	5(36)	5(71)	21(38)	36(75)	26(37)	41(75)

\*Some valves exhibited only encrustations and other valves only borings, yet most exhibited various combinations of the two.

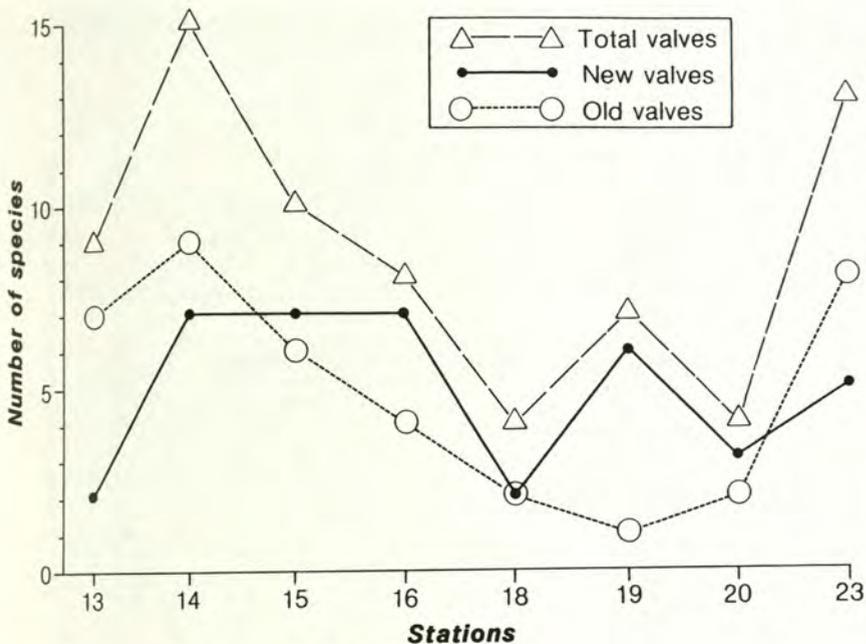


Fig. 3. Diversity of detrital mollusk shells.

ward ends of the transect (Fig. 2A), whereas new shells predominated at most sites in between. Too few shells were recovered at Stations 18 and 20 to depict a trend. New to old valve ratios (Fig. 2B) thus increased dramatically along the central part of the traverse.

The new:old ratio for total shells (1.27) was substantially less than ratios reported by Henderson and Frey (1986) from: (1) shallow sound sites off the southern end of Sapelo Island (7.36); (2) a longshore tidal channel immediately adjacent to the southeastern end of the beach (81.11); and (3) the nearshore shelf at the seaward end of the channel (where old shells were virtually absent). The difference in ratios indicates a substantially longer in-loco residence time for lower offshore shells than for nearshore shelf and sound shells. A corollary is the slow rate of deposition of offshore sediments relative to that of nearshore shelf and sound sediments (Howard and Reineck, 1972; Mayou and Howard, 1975).

#### Encrusting and Boring

Of the 125 specimens examined, 37% of new and 75% of old shells were invested

with various combinations of borings and/or encrustations (Table 1). These associated organisms (or their lebensspuren) cannot be termed *epibionts* or *endobionts*, sensu stricto, because most were not coeval with the original, live mollusks; rather, the shells in most cases were utilized simply as rigid substrates (cf. Ekdale, 1985, p. 66, Fig. 1). In numerous specimens, both interior and exterior valve surfaces were occupied.

The most prevalent encrusters were several unidentified species of calcareous (chiefly cheilostome) bryozoans. Next most important were the calcareous tubes of various unidentified species of serpulid worms. Bivalve spat and acorn barnacles (Table 1) were substantially less common. Most of the tiny spat probably are referable to the bivalve *Anomia simplex*, although some possibly are referable to *Pododesmus rudis*. The barnacles included species of both *Balanus* and *Chathalmus* (rarely), and all individuals were small.

Among borings, the cavity networks of clionid sponges were predominant; these are equivalent to the trace fossil ichnogenus *Entobia* (Bromley, 1970; Brom-

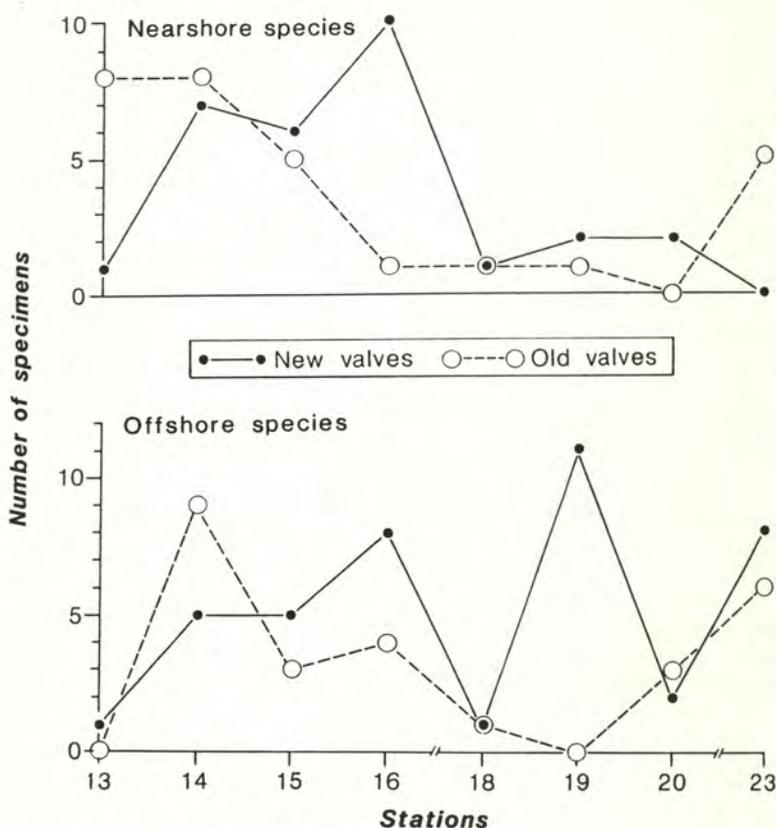


Fig. 4. Relative abundance of detrital mollusk shells with respect to inferred original environmental distribution.

ley and D'Alessandro, 1984). The small, slit-like excavations of acrothoracican barnacles, most of them equivalent to the ichnogenus *Rogerella* (Häntzschel, 1975), were common locally. Borings by gastrochaenid clams, referable to the ichnogenus *Gastrochaenolites* (Kelly and Bromley, 1984), included both small, pouch-like excavations in shells and well-cemented, agglutinated assessor tubes or "blisters" (cf. Warme, 1975, Fig. 11.25); several cavities still contained the valves of *Gastrochaena hians* (Appendix). No attempt was made to differentiate algal and fungal microborings (see Golubic *et al.*, 1975), which were common on some valves.

Boreholes made by predaceous gastropods, referable to the ichnogenus *Oichnus* (Bromley, 1981), were more com-

mon among new valves than among old valves (Table 1). Most of these holes were located in the umbonal region of bivalves; the style of penetration suggests that naticid gastropods such as *Polinices duplicatus* were responsible (see Carriker and Yochelson, 1968).

Altogether, the intensity of boring or encrustation is related more closely to the duration of shell exposure at the sediment-water interface than to the absolute age of the shell itself. One season of exposure to larval settling and metamorphosis is sufficient to initiate these processes, whether the host substrate is a recently dead Holocene or a long-buried but recently exhumed Pleistocene shell. On a probability basis, however, older shells are more apt to have been exposed longer or more often than newer shells. Thus, the fre-

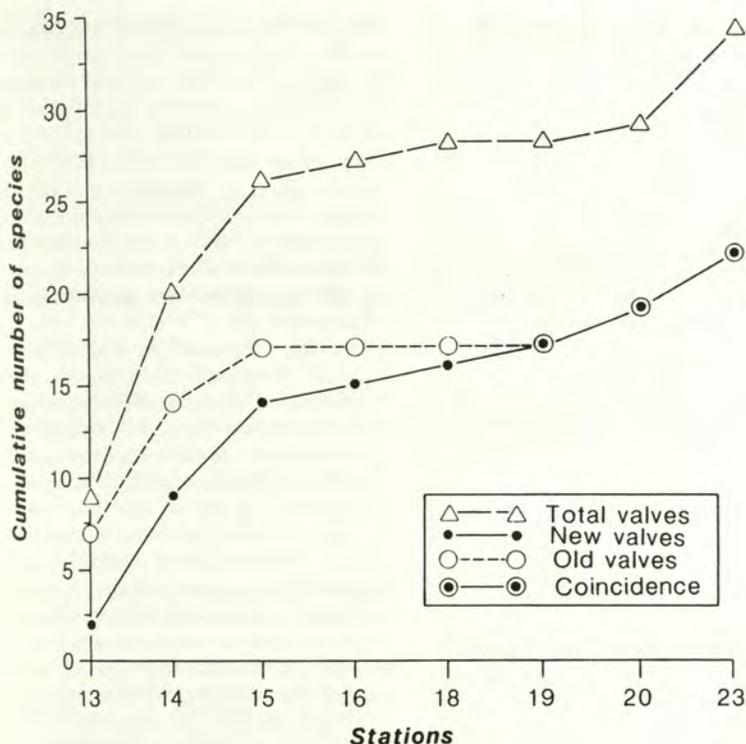


Fig. 5. Qualitative species-area curves for detrital mollusk shells.

frequency and extent of boring and encrustation are general indicators of relative antiquity within the total assemblage (Table 1), but little reliance may be placed upon the temporal significance of any given specimen. A corollary mentioned previously is the slow rate of deposition on the offshore shelf in this area, which prolongs the in-loco exposure time for surficial shells.

#### Shell Diversity and Provenance

Altogether, shells of 10 species of gastropods and 24 species of bivalves were identified (Appendix). Shells of small species, such as those of the gastropod *Turbonilla*, probably were lost through the coarse mesh of the sieve (2.5 mm). Total diversity within the size fraction examined was substantially greater on the landward part than on the seaward part of the transect (Fig. 3), even though the assemblage at the seaward end (Station 23) was more di-

verse than those at closely adjacent sites. This trend was even more pronounced among old shells; species of new shells were somewhat more evenly distributed, especially considering the paucity of all shells at Stations 18 and 20 (Fig. 2A). These differences suggest that the newer shells represent relatively consistent, recent, penecontemporaneous conditions, whereas older valves reflect either a present or a previous environmental zonation (as during a lower stand of sea level; Rollins *et al.*, 1979) or subsequent redistribution and selective redeposition of relict shells by physical processes (*cf.* Pilkey *et al.*, 1978).

In further evaluation of these possibilities, shell assemblages may be divided into nearshore and offshore components (Pilkey *et al.*, 1969b). The following 16 species of shells have been reported from beaches and/or the nearshore shelf off Sapelo Island (Dörjes *et al.*, 1986; Hender-

son and Frey, 1986; Frey and Dörjes, in prep.), and hence may be considered as the nearshore component of the total assemblage (Appendix):

**GASTROPODS**

*Crepidula fornicata*

*Diodora cayenensis*

*Oliva sayana*

*Polinices duplicatus*

*Terebra dislocata*

**BIVALVES**

*Anadara ovalis*

*Anadara transversa*

*Anomia simplex*

*Crassostrea virginica*

*Dinocardium robustum*

*Eucrassatella speciosa*

*Lucina pectinata*

*Lucina radians*

*Mulinia lateralis*

*Spisula solidissima similis*

*Strigilla mirabilis*

Of these, *Diodora cayenensis*, *Eucrassatella speciosa*, *Lucina pectinata*, and *Lucina radians* are least common in nearshore or intertidal settings. The remaining 18 species (Appendix) are taken as the offshore component:

**GASTROPODS**

*Cerithium atratum*

*Conus delessertii*

*Conus jaspideus stearnsi*

*Strombus alatus*

*Turritella acropora*

**BIVALVES**

*Arcinella cornuta*

*Argopecten gibbus*

*Chama congregata*

*Chione intapurpurea*

*Gastrochaena hians*

*Glycymeris undata*

*Laevicardium pictum*

*Linga pensylvanica*

*Macrocallista maculata*

*Macrocallista nimbosa*

*Pecten raveneli*

*Tellina aequistriata*

*Tellina listeri*

All the above habitat assignments refer mainly to Georgia waters; latitudinal variations in habitat adaptations, and therefore in detrital shell distributions, are exhibited by some Atlantic-Gulf mollusk species (cf. Parker, 1960, 1969; Bird, 1970). By these criteria, the landward abundance of shells (Fig. 2A) is attributable to a mixture of offshore and nearshore components (Fig. 4), especially with respect to old valves. In contrast, the seaward end of the traverse is

characterized by shells of offshore species. Equally important, these results show that old shells *per se* are not simply a relict suite of nearshore species (cf. Pilkey *et al.*, 1969b, p. 765); many specimens from the offshore component are equally "relict", or old-appearing. Nevertheless, new to old valve ratios are appreciably smaller among nearshore shells (0.97) than among offshore shells (1.58), reflecting a continuing dilution of the total assemblage by new offshore shells.

Trends depicted in Figure 4 further suggest predominantly in-loco shell accumulations along a crude environmental gradient rather than pronounced local concentrations of shells by physical processes. Even though some landward, physical displacement of shells may have occurred, the simplest explanation is that this area merely represents a transition between upper offshore and mid-shelf type shell deposits—the nearshore component being expressed best at the landward margin and the offshore component being developed best at the seaward margin of the zone.

This conclusion is supported to some extent by a qualitative species-area curve (Fig. 5), which also serves as a crude measure of sampling adequacy. "Plateaus" along the curves indicate that sampling was generally adequate through most of the transect, especially with regard to old shells (and to total shells, if no distinction is made between new and old valves); yet, the collections are only marginally representative of species diversity among new shells. Acceleration of the curves at Station 23 might be interpreted as sampling inadequacy; however, preliminary examinations of bulk assemblages from box cores taken farther offshore (Howard and Frey, 1980, Fig. 5) indicate a persistent, dramatic increase in abundance and diversity of middle- and outer-shelf shells per unit volume of sediment—attributable mainly to extremely slow rates of deposition there (except at the shelf-slope junction, where fine sediments are accumulating today) and the influence of the Gulf Stream (increased seaward diversification among benthos; Hanson *et al.*, 1981).

In short, the seaward end of the transect, which is three nautical miles from the nearest landward station (Fig. 1), is

deemed to be a normal part of the transition to conditions farther offshore and an integral part of the crude environmental gradient mentioned above. Abundance of nearshore shells evidently increases landward for the same reasons.

#### V. ACKNOWLEDGMENTS

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## VII. APPENDIX

### MOLLUSKS FROM OFFSHORE SHELF

Taxonomic checklist and summary of new and old valve distributions, detrital mollusk shells off Sapelo Island.

New/Old Mollusk Shells	Stations								Total
	13	14	15	16	18	19	20	23	
<b>GASTROPODS</b>									
<i>Cerithium atratum</i> (Born)	-	1/-	-	-	-	-	-	-	1/-
<i>Crepidula fornicata</i> (Linné)	-	-/2	-	-	-	-	-	-	-/2
<i>Conus delessertii</i> Récluz	-	-	-	-	-	-	-	1/-	1/-
<i>Conus jaspideus stearnsi</i> Conrad	-	-	-/1	-	-	-	-	-	-/1
<i>Diodora cayenensis</i> (Lamarck)	-/1	-	-	-	-	-	-	-	-/1
<i>Oliva sayana</i> Ravenel	-/1	1/-	-/1	2/1	-	-	-	-	3/3
<i>Polinices duplicatus</i> (Say)	1/-	-	-	-	-	-	-	-	1/-
<i>Strombus alatus</i> Gmelin	-	-	-	-	-	-	-	1/-	1/-
<i>Terebra dislocata</i> (Say)	-	-	1/-	3/-	-	1/-	-	-	5/-
<i>Turritella acropora</i> Dall	-	-	-	-	1/-	1/-	-	-	2/-
<b>Total Gastropods</b>	<b>1/2</b>	<b>2/2</b>	<b>1/2</b>	<b>5/1</b>	<b>1/-</b>	<b>2/-</b>	<b>-</b>	<b>2/-</b>	<b>14/7</b>
<b>BIVALVES</b>									
<i>Anadara ovalis</i> (Bruguère)	-/1	-	-	-	-	-	-	-	-/1
<i>Anadara transversa</i> (Say)	-/2	-	-	-	-	-/1	-	-	-/3
<i>Anomia simplex</i> Orbigny	-	4/-	2/-	5/-	-	-	2/-	-/1	13/1
<i>Arcinella cornuta</i> Conrad	1/-	-/2	-	1/1	-	2/-	-	-	4/3
<i>Argopecten gibbus</i> (Linné)	-	-	1/1	-/1	-/1	-	-	-/1	1/5
<i>Chama congregata</i> Conrad	-	-	-	1/-	-	-	-	3/-	4/-
<i>Chione intapurpurea</i> (Conrad)	-	-	2/1	3/2	-	6/-	-	-/3	11/6
<i>Crassostrea virginica</i> (Gmelin)	-	-	-	-	-	-	-	-/1	-/1
<i>Dinocardium robustum</i> (Lightfoot)	-	-/1	-	-	-	-	-	-	-/1
<i>Eucrassatella speciosa</i> (Adams)	-	-	-	-	-	-	-	-/1	-/1
<i>Gastrochaena hians</i> (Gmelin)	-	2/-	-	3/-	-	2/-	-	-	7/-
<i>Glycymeris undata</i> (Linné)	-	1/-	-	-	-	-	-	-	1/-
<i>Laevicardium pictum</i> (Ravenel)	-	-	2/-	-	-	-	-/2	2/-	4/2
<i>Linga pensylvanica</i> (Linné)	-	-/2	-	-	-	-	-	-	-/2
<i>Lucina pectinata</i> (Gmelin)	-/1	-	-	-	-	-	-	-	-/1
<i>Lucina radians</i> (Conrad)	-/1	-/2	-	-	-	1/-	-	-	1/3
<i>Macrocallista maculata</i> (Linné)	-	-/2	-	-	-	-	1/-	-/2	1/4
<i>Macrocallista nimbose</i> (Lightfoot)	-	-/2	-	-	-	-	-	-	-/2
<i>Mulinia lateralis</i> (Say)	-	-	-/3	-	-	-	-	-/1	-/4
<i>Pecten raveneli</i> Dall	-	-	-	-	-	-	1/1	-	1/1
<i>Spisula solidissima similis</i> Say	-/1	2/3	2/1	-	-/1	-	-	-/1	4/7
<i>Strigilla mirabilis</i> (Philippi)	-	-	1/-	-	1/-	-	-	-	2/1
<i>Tellina aequistriata</i> Say	-	1/-	-	-	-	-	-	-	1/-
<i>Tellina listeri</i> Röding	-	-	-	-	-	-	-	1/-	1/-
<b>Total Bivalves</b>	<b>1/6</b>	<b>10/15</b>	<b>10/6</b>	<b>13/4</b>	<b>1/2</b>	<b>11/1</b>	<b>4/3</b>	<b>6/11</b>	<b>56/48</b>
<b>Total Mollusks</b>	<b>2/8</b>	<b>12/17</b>	<b>11/8</b>	<b>18/5</b>	<b>2/2</b>	<b>13/1</b>	<b>4/3</b>	<b>8/11</b>	<b>70/55</b>

## REVIEW

beginnings of the planet Earth, its sister planets, and the Sun, as well as the emergence of life upon Earth.

In *Contributions of Individuals*, Robert Dott describes James Hall's Discovery of the Craton and recognition of the fundamental difference between the central plate and the bordering orogenic belts, emphasizing that Hall himself was much more interested in acquiring and describing fossils and extending our knowledge of stratigraphy than in publishing his mountain building theory; George Merk reviews the controversial concepts of E. O. Ulrich which supported and fostered the Wernerian "onion peel" or "layer-cake" geology in America during the first three decades of the twentieth century even though the concept that stratigraphic and faunal units normally end in a facies change was in common usage in Europe at the time. Additional essays deal with the pioneer geologist J. A. Udden and his research on wind-blown sediments that led to the particle distribution scheme used by modern sedimentologists, the Udden-Wentworth scale; R. S. Tarr, one of the pioneers of glacial geology and physical geography who devoted his brief professional life to the study of ice masses and the effects that they have had on the landscape; L. R. Wager and the Geology of East Greenland; Dr. Atl, Pioneer Mexican Volcanologist and muralist; and, Joseph A. Cushman and the Study of Foraminifera, including a review of his life work on the description and classification of these organisms which have had such a profound effect on subsurface geology and correlation, and of the famed controversy with J. J. Galloway over the publication of their respective classifications. The last paper in this section, Wrong for the Right Reasons: G. G. Simpson and Continental Drift describes the opposition to Continental Drift of this pre-eminent geologist who was wrong about Continental Drift and used his own historical biogeography based on Cenozoic mammals to refute the theory.

The third section, *Contributions of Organized Groups*, begins with Surveying the Geology of a Vast, Empty, Cold Country, the enormous task of taking inventory of Canada's minerals, rocks, and fossils, so

overwhelming that "numberless difficulties inherent in such an undertaking, embracing a range of country so vast and so difficult to explore, or even to obtain access to, must necessarily render any attempt of this nature very imperfect" (Isbister, 1855). The geological description of the second largest country on Earth (nearly ten million square kilometers) began with the establishment in 1842 of the Geological Survey of Canada, headed by William Edmund Logan. The early work began with travel by canoe or on foot under conditions arduous at best and confronted a vast and empty hinterland so sparsely populated that no more than 100,000 indigenous persons dwelt there. Even today, more than 20 of Canada's 24 million people live within a narrow southern strip bordering the United States and extending along its maritime provinces. McGill College, founded at Montreal in 1821 by Royal Charter, became McGill University in 1843. John William Dawson became its head in 1855 and remained for 38 years, never yielding from his fundamentalist views on the origin nor from his opposition to the theories of organic evolution and continental glaciation. He exerted enormous influence on early Canadian science. That so much scientific progress took place during the nineteenth century is an everlasting tribute to the stalwart pioneers of Canadian geological investigation. Other papers in this section are concerned with the Contributions of the State Geological Surveys (many founded by the students of Benjamin Silliman); the Role and Development of the Smithsonian Institution in the American Geological Community, the unsurpassed contributions of both the institution and its personnel (so ably recounted by Ellis Yochelson); A Brief History of the Geological Sciences at Yale, beginning with the appointment of Benjamin Silliman as Professor of Chemistry and Natural History in 1802, continuing with James Dwight Dana (1850) and through five more generation-long stages (the seventh and last beginning in 1965); and, A History of Geology at the University of Pennsylvania, from the early ruminations on diverse geological and geophysical matters by Benjamin Franklin, John Bartram, Benjamin Smith