VOLUME 86 NUMBER 3

THE JOURNAL OF GEOLOGY

May 1978

GLOBAL DISTRIBUTION OF BARRIER ISLANDS IN TERMS OF TECTONIC SETTING[1]

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ABSTRACT

Measurements of the global abundance of barrier islands indicate that 49% occur along coastlines of trailing continent margins; 24%, along collision plate margins; and, 27%, along coasts of marginal seas. Based on 2619 shelf width measurements, evidence is presented to show that for only trailing margins is shelf gradient related to barrier island abundance. Of those barrier islands situated along trailing margin coasts, 75% occur along Amero-trailing margins (average gradient 0.57 m/km); 19%, along Afro-trailing margins (average gradient 2.4 m/km); and, 6% along Neo-trailing margins (average gradient 5.9 m/km). Because sediments supplying barrier islands today are generated mainly on the inner shelf and shoreface in response to both nearshore processes and to rising sea level, barrier islands occur in greatest abundance where broad, low-relief coastal plains lie adjacent to the inner shelf and where both are comprised of abundant unconsolidated detritus. Elsewhere, barrier island occurrence is sparse to absent along very low gradient shelves where the coastal plain-continental shelf sedimentary prism is absent. The tectonic setting of the continental margin is fundamental in controlling factors governing barrier island abundance.

INTRODUCTION

This paper considers the tectonic setting of coastlines in explaining the global distribution of barrier islands. Comparison is made between the abundance of barrier islands and the tectonic setting of continent or plate margins along which this coastal environment is developed. It has been assumed for some time that there are three factors which directly relate to barrier island occurrence. These are low gradient continental shelves, abundant sediment supply (King 1972, p. 527) and moderate to low tidal ranges (Gierloff-Emden 1961). In this present paper the first two of these factors, sediment supply and shelf gradient, are examined in terms of barrier island abundance along each tectonic type of coastline. It is demonstrated that the percent of coastline length occupied by barrier islands is directly correlatable to plate-margin type. Differences in tectonic type of plate margin may help explain the basic controls of barrier island abundance. There are some important first order geologic relationships brought out here between the distribution of barrier islands and tectonic settings of the world's coastlines which may contribute to the present thinking on barrier island genesis.

The influence of tidal range on barrier island occurrence is beyond the scope of this paper. During the compilation of data used in this study, it was observed that only 10% of the world's barrier islands are present along coastlines where the tide ranges exceed 3 m. These areas are listed in the Appendix. However, there is no apparent link in the data presented here to

[1] Manuscript received April 25, 1977; revised September 27, 1977.

[JOURNAL OF GEOLOGY, 1978, Vol. 86, p. 283–297]

0022-1376/78/8603-0001$01.30

explain any association between tide range and tectonic setting of the coastline.

Procedures.—Lengths of coastlines along all the world's oceans and the lengths of all barrier islands present were measured. The base map used for these measurements was McGill's (1958) "Map of Coastal Landforms of the World (scale 1:25,000,000)." This base map is an equal-area projection and, therefore, the cumulative lengths of all barrier islands along any particular coastline are expressed as a percentage of the total length of that coastline. All data compiled for this study are given in the Appendix. McGill (p. 405) states: "Barrier beach, barrier island, barrier spit or bay barrier is separated from the coast proper or from the immediate coastal interior by a lagoon, swamp or other shallow water body." It is the lengths of these features which were measured from McGill's (1958) map in the present study and collectively are termed here, "barrier islands."

Barrier islands were then related to tectonic type of coastline using the coastline classification of Inman and Nordstrom (1971). They differentiated between coastal geomorphic characteristics of collision and trailing plate margins, subdividing the latter type into Amero-, Afro-, and Neo-trailing margins. This subdivision of trailing margins has been particularly important in the present paper because Inman and Nordstrom (1971) showed that the continental shelves of each of these three types can be distinguished in terms of both shelf width and sediment volumes which have been supplied to them.

Coastlines of all continents were measured except for the small land masses of Madagascar, Iceland, and Tasmania. Coastline lengths and their associated barrier islands were measured for island arcs along both the coastlines facing marginal seas and those facing the trench sides. The mainland edges of the Arctic sea include data from only northwestern North America and the Eurasian landmass. Because of the Antarctic ice shelves, there is no way of evaluating the physical character of Antarctica's coastlines in terms of barrier island development and, therefore, no measurements were made of that continent.

In addition to the data relating barrier island lengths to coastline lengths, shelf widths were measured using a global map of major topographic divisions of continent and island arc margins (Heezen and Tharp 1970). Based on 2619 shelf width measurements and an arbitrary 200 m shelf break depth, shelf gradients were determined for each tectonic type of coastal margin. These are given in the Appendix.

McGill (1958) points out that his coastal landforms map is a first approximation and it is probable that some barrier islands of the world are not included on his map and thus not part of the tally presented here. In addition, new interpretations of tectonic character of any plate margin may modify the coastline classification of Inman and Nordstrom (1971) applied throughout this paper.

BARRIER ISLAND ABUNDANCE IN RELATION TO TECTONIC SETTING OF COASTLINES

Data from the Appendix are summarized in figure 1 showing results of global measurements of coastline lengths and the percentage of those lengths occupied by barrier islands. Twelve percent of the globe's coastlines along trailing plate margins are occupied by barrier islands; 8% of the coasts along collision margins have barrier islands, and 9.6% of marginal sea coasts are lined with barrier islands. At first glance, these percentages seem undramatic and, along with the distribution of barrier islands in terms of total barrier island length shown in figure 1, might suggest a simple relation between total coastline length and barrier island abundance. Observe in figure 1 that 49% of the world's barrier islands occur along trailing margins; 24%, along collision margins; and 27% along marginal sea coasts. These proportions might seem to follow only from the fact that globally, length of coastlines of both collision margins and of marginal seas are about 30% less than the lengths of coastlines along trailing margins. A binomial distribution was used to test the possibility that, because trailing margins coastlines are longer, proportionately more barrier islands would be associated with them. The statistical tests applied revealed that 4.75 standard deviations separate the percent of barrier islands along collision versus trailing margins and 4 standard deviations separate observed

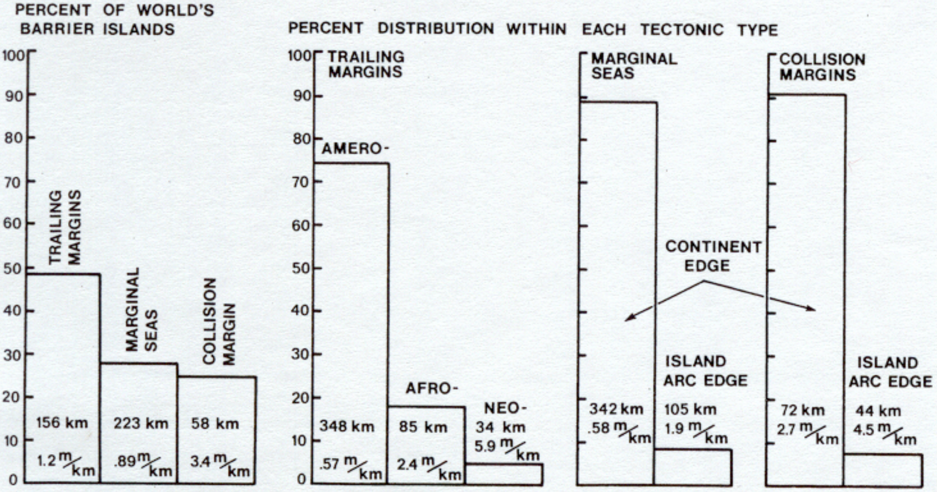

FIG. 1.—Barrier island distribution and abundance in terms of tectonic setting. Histograms of percent coastline length occupied by barrier islands. Tectonic type of coastline based on Inman and Nordstrom (1971). Data used in compiling histograms listed in Appendix.

values for marginal sea coasts versus trailing margins. Thus, a real difference in barrier island abundance exists which is not a simple function of total coastline length of type of tectonic margin.

An explanation for the data given in figure 1 can be linked to findings of Inman and Nordstrom (1971) who showed that sediment discharge from rivers draining toward trailing margin coastlines far exceeds the discharge of rivers draining toward collision margins. Further, they showed that there are differences in sediment volumes delivered to each of three types of trailing continent margins, distinguished principally by their shelf width. They showed that, by far, the largest sediment volumes are delivered to the Amero-trailing margin. This type of plate is characterized by drainage asymmetry where the drainage divide is located near the opposite side of the continent (the collision boundary) causing the bulk of the sediment to be carried toward the trailing margin. Measurements made in the present study show that 75% of all barrier islands present along trailing margins occur along this Amero-type margin (fig. 1).

The smallest sediment discharge is delivered to coastal regions of continental crust in the early stages of separation, such as the coastlines of the Gulf of California and of the Red Sea. Inman and Nordstrom (1971) called these types of coastal margins, neo-trailing margins. Such plate margins have narrow, if any, continental shelves, and landward, the drainage basins are relatively small. The neo-trailing margins of the Red Sea and the Gulf of California were measured and have only 5.6% of the total length of barrier islands found along trailing margins (fig. 1).

Inman and Nordstrom (1971) defined the Afro-trailing margin as an intermediate geomorphic trailing margin type of coastal setting in terms of shelf width and volume of sediment delivered from continental interior. As exemplified by Africa, this type of continent shows a general symmetry of drainage toward most of its margins because the principal lengths of its margins face spreading centers. Mountains do not dominate a particular narrow, well-defined zone within the land mass. This intermediate character of both sediment discharge and shelf width is reflected in the data given in figure 1. Coastlines of Afro-trailing margins have 19.5% of all barrier islands measured along trailing continent margins.

Averages based on detailed measurements (in Appendix) of shelf width and gradient are given in table 1. Amero-type continental shelf margins

TABLE 1

SHELF WIDTH AND GRADIENT AVERAGES IN TERMS OF TECTONIC TYPES OF COASTLINE MARGINS

	Shelf Width (km)	Shelf Gradient (shelf break −200m)
TRAILING MARGINS		
Amero-	348	.57 m/km
Afro-	85	2.4
Neo-	34	5.9
Average	156	1.2
COLLISION MARGINS		
Continents	72	2.7
Trench sides of island arcs	44	4.5
Average	58	3.4
MARGINAL SEAS		
Continents	342	.58
Island arcs	105	1.9
Average	223	.89

NOTE—Data used listed in Appendix. Based on 2619 shelf-width measurements made from map by Heezen and Tharp (1970).

average 348 km in width and have a gradient of 0.6 m per km. Afro-trailing continental shelves average 85 km in width and have a gradient of 2.4 m per km. Neo-trailing continental shelves are narrowest and steepest: 34 km in average width; 5.9 m per km average gradient. Thus, it is clear in comparing data from figure 1 with those in table 1 related to trailing margins, that the greatest abundance of barrier islands occurs along the widest, lowest gradient trailing margin shelves (Amero-trailing margins). With decreasing shelf width and increasing gradient, the abundance of barrier islands along coasts of trailing continent margins decreases proportionately. To test this hypothesis of tectonic association beyond the neat relationships shown here for trailing margins, it is necessary to look at measurements of barrier islands along collision margins and along coastlines of marginal seas (data in Appendix).

Collision margins.—Collision margin coastlines are subdivided into two categories: coastlines of the trench side of island arcs and coastlines of continental margins in collision with oceanic crust. In terms of total length of barrier islands measured along all collision margins, 92% occur along coastlines of continents and only 8% occur along the trench edge of island arcs (fig. 1). Similarly, only 10% of barrier islands measured along coastlines of marginal seas occur on the island arc side and 90% occur along the mainland coasts. Clearly, neither side of an island arc system has a broad shelf nor does the island arc system itself yield sediment volumes comparable to discharge quantities derived from continental land masses.

Shelf width and gradient data listed in the Appendix are summarized in table 1. Collision margin coasts have an average width of 58 km and average gradient of 3.4. The contrast of these values to those shown for trailing margins is, in part, a result of averaging collision margins of continents and of the trench sides of island arcs. Shelf width values for collision margins of continents alone are roughly half those shown for trailing margins and thus gradients are a little more than twice as steep.

To further assess the effects of shelf width and gradient on barrier island abundance, it is of interest to examine the data for barrier island distribution along the collision margin coastline of the western Americas. Of those sites where barrier islands occur (listed in Appendix), 60% of the barrier islands along collision margins of continents are situated along the coasts of the Central American nations, Mexico, Guatemala, El Salvador, Nicaragua and Costa Rica. In terms of coastline length, this coastal zone of western Central America represents a very small portion of the total coastline length from Alaska to the southern tip of Argentina. This zone of western Central America is associated with the Cocos plate.

Shepard (1973, p. 233) indicates that north of the Gulf of Panama to latitude 11°15′N, this portion of shelf is narrow to non-existent. Here there are no barrier islands. But, further to the north, Shepard (p. 233) points out that the shelf widens to 55 km and continues wide on the west side of the Gulf of Tehuantepec where there is a maximum width of 100 km. Again, between Puerto Angelo and Puerto Vallarta, the shelf is essentially non-existent. In this stretch, barrier islands are absent as well. According to Shepard's (p. 233) continuing description, the shelf from just south of San Blas has appreciable width and this relatively wide shelf extends from north of Mazatlan into the mouth of the Gulf of California. Along these portions of the Central American coastline where barrier islands are present, the adjacent coastal plain (relief less than 200 m) averages 56 km width, broader than most other regions along the coast of the western margin of the Americas. Shelf gradient here is 3.6 m/km.

Another anomalously high percentage of barrier islands is shown by McGill (1958) along the Pacific coast of Baja, California. The average width of the landward area adjacent to the coasts where elevations do not exceed 200 m above sea level is 25–40 km. In contrast, where extensive barrier islands occur at San Ignacio and along Ilano de la Magdalena, widths are around 50–60 km.

Lack of abundant barrier islands along other portions of collision coasts apparently relates not only to the generally narrow, steep shelf but also to the presence of submarine canyons which head at places along the inner shelf in the littoral zone itself. Inman and Frautschy (1966) observed that there was significant sand loss from the coastal zone of California because of sand movement down these "near-shore" submarine canyons.

Marginal Seas.—The summarized values for marginal seas listed in table 1 show that shelf widths of continent margins are more than twice the average width of trailing continent margins and the gradients about half as steep but do not have a higher percentage of barrier islands. This implies that shelf width and gradient alone are not the unique controls favoring barrier island abundance.

Relevance of shelf gradient to barrier island abundance.—A closer examination of the specific shelf gradient data presented in the Appendix would suggest that barrier islands are present along coasts having a variety of shelf gradients. In reference to shelf gradient and barrier island abundance along the Asia mainland (facing marginal seas) and eastern North America (Amero-trailing margin), the following data are offered:

	% coastline length occupied by barriers	gradient (m/km)
Asia mainland	7	0.8
North America	27	1.6

Nearly four times the percentage of barrier islands occur along eastern North America where the shelf gradient is twice the steepness of the shelf adjacent to the Asia mainland. This raises three important questions. First, is there an upper limiting shelf gradient steepness beyond which barrier islands are not likely to occur? A tally made of gradient values for segments of coastlines of all continents given in the Appendix fails to suggest any limit. For example, barrier islands are shown in McGill (1958) along the coast of New Zealand where the gradient is determined to be a steep 26.6 m/km.

The second question raised concerns the range of gradient values where no barrier islands were noted. The listing below suggests that low gradient alone is no "guarantee" of barrier island occurrence. This listing gives shelf gradient values for those coastline segments of continents where *no* barrier islands are present.

Trailing m/km	Collision m/km	Marginal Seas m/km
1.8	1.5	0.5
3.1	2.7	0.9
10.4	24.0	

The third question is whether coastlines occupied by significant lengths of barrier islands (say, 20% or more of the total coastline length is barrier island) show any similarities in shelf gradient values. The tally below shows that the range of values is broad, with the steepest value reaching 5.1 m/km (meaning shelf width of about 50 km).

Trailing m/km	Collision m/km	Marginal Seas m/km
0.45	5.1	0.2
1.6		1.8
1.9		2.02
4.5		
4.6		

A further check was made to determine whether there was any trend between decreasing percentages of barrier islands and increasing shelf gradient values. No trend is present in the data listed in the Appendix. Thus, it would appear from all of the data given that shelf gradient alone fails to account for barrier island abundance along coastlines of any type of continent margin.

Relevance of river sediment discharge to barrier island abundance.—Is it possible that river sediment discharge from the adjacent mainland is, by itself, a controlling factor? This question is difficult to assess for two reasons. Adequate sediment discharge data are lacking for rivers emptying into the coastal environment of many regions. The second difficulty is the absence of definition of grain size of the discharge load. Amounts of sand brought by rivers to the coastal zone is the critical factor which is lacking. Nonetheless, it may be possible to assess the relation between river discharge and barrier island abundance even with these limitations.

Table 2 lists sediment discharge from the Asia mainland taken from Inman and Nordstrom (1971, table 2, p. 8–9). The Huang Ho, Mekong and Yangtze Rivers rank first, sixth and eighth, respectively, in terms of annual sediment yield for rivers of the world. Despite these high sediment yield values to the Asia mainland coast there are *no* barrier islands along the coast of China. The only barrier islands present along the Asia mainland lie along the coasts of the Gulf of Tonkin, the Gulf of Thailand on the northeasternmost Malay peninsula and along North Korea in the Sea of Japan (McGill 1958).

TABLE 2
SEDIMENT DISCHARGE FROM ASIA MAINLAND INTO MARGINAL SEAS OF NORTHWEST PACIFIC

River	Suspended Sediment Load (10^6 tons/yr)
Amur	52
Hwang Ho	1850–630
Yangtze Kiang	500–275
Red	130
Mekong	1000
Chao Phraya	11–5
Total	3,543–2,092

NOTE—Values exceed combined values of suspended sediment loads (10×10^6 tons/yr) of all rivers draining eastern United States (Meade and others, 1975) by a factor of 200–300. Discharge data from Inman and Nordstrom (1971).

In spite of the general absence of barrier islands, the rivers of eastern Asia exceed by a factor of 200–300 the combined sediment yield from all rivers draining to the coastline of eastern United States (Meade and others 1975) where one of the world's most extensive chains of barrier islands occurs. This contrast in river sediment load versus barrier island abundance takes on added significance when viewed in two ways. First, virtually the entire sediment discharge from estuary mouths along the eastern United States coastline is silt-size and finer (Meade 1969). Second, only 10% of that material escapes the estuaries (Meade and others 1975). Clearly, that material which does escape the estuary mouths today does not contribute to the sand budget of the United States east coast beaches. Thus, the sands of those barrier islands is not related to present-day river discharge. Because the bulk of the rivers of the world today are not building deltas, there is no immediate link between river sediment discharge and barrier island abundance.

APPLICATION OF RESULTS TO BARRIER ISLAND GENESIS DEBATE

It is evident from the data presented here that earlier assumptions of shelf gradient and sediment supply as two of the controlling factors of barrier island abundance may be applicable only to trailing margin coastlines. Along other tectonic types of coastlines, neither low gradient nor abundant sediment supply can be linked to the presence or absence of barrier islands. It is also evident that sediment supplied by present-day river systems appears to have little, if any, bearing upon barrier island development.

Clearly the problem bearing upon barrier island abundance is related to the availability and abundance of sediment in the shoreface zone and the response of the coastal zone to shoreface retreat.

Two papers dealing with barrier island genesis (Swift 1975; Field and Duane 1976) have focused directly upon the process-response requirements of barrier island development. Both papers assess the response to sea-level rise in terms of shoreface retreat and the role played by inner shelf sedimentary processes.

Field and Duane (1976, p. 695) suggest that, in the light of the low rate of terrigenous sediment supply to the inner continental shelf surface, modern surficial sands of the shoreface and inner shelf are reworked, derived from the adjacent shelf or contributed directly from headland and barrier erosion and retreat. Swift (1975, p. 8) observes that with decreasing gradient, there is an increasing likelihood for the upper erosional zone of the shoreface to extend down into the pre-Recent substrate resulting in erosion of the inner shelf floor. Under such conditions, Swift (1975, p. 18) considers this sediment source to be as important as that from headland erosion under conditions of subdued relief.

Under these optimum, ideal conditions, there should be a close association between barrier island systems and broad, low relief coastal plains. If we consider the coastal plain zone as simply the subaerial portion of the continental shelf, the overall relief and slope should be generally the same as the shelf surface over which the sea is rising. Where the coastal plain is a constructional feature comprised of prograded sedimentary materials extending toward the shelf break, the geomorphic relations today among coastal plain-shoreface-inner shelf are virtually identical to those developed when transgression followed still-stand and regression. Since that reversal of sea-level, shoreface retreat, as suggested by Swift (1975) and by Field and Duane (1976), has resulted in the hydraulic response of the shoreface and inner shelf which is accountable for development, maintenance and landward migration of barrier island systems. Field and Duane (1976, p. 695–696) cite evidence that the present configuration of the coastline of the middle Atlantic of the United States is generally the same as that throughout the Holocene transgression. This consistency is recorded in orientation of cape and inlet associated shoals seen in the morphology of the inner shelf.

Presence of broad, low relief coastal plains links directly to tectonic setting of the continent margins and is simply an extension by analogy of Inman and Nordstrom's (1971) initial thesis explaining shelf width and sediment abundance. It may be possible then to explain the association of barrier islands with coastal plain characteristics themselves and to test the idea that barrier islands develop most readily along those shelves having an associated low relief coastal plain.

Three types of coastlines examined in the previous section can be considered in terms of the presence of a low-relief coastal plain. The first is the abundance of barrier islands along the Amero-trailing margin of eastern North America which contrasts to the broader, lower gradient shelf along the Asia mainland. There, sediment discharge to the coastal zone exceeds that of eastern North America by a factor of 200–300. Yet the barrier islands along the Asia mainland are sparsely distributed in comparison to those of eastern North America. The explanation for this difference appears to lie in the nature of the geomorphology of the land surface adjacent to the coastline. Most of the western margin of the Asia mainland is a vast area of hills and relatively narrow, intervening lowlands occupied by a complex drainage network. With the exception of the broad plains north of Hangchow, the width of the low-lying land area adjacent to the Asia mainland coast is 25 km and less. In eastern North America, the coastal plain broadens from New Jersey southward with widths adjacent to the middle Atlantic Bight of 150–200 km.

A second area which shows a close link between barrier island abundance and the presence of a low relief coastal area is the site along the collision margin of western Central America where an anomalously high concentration of barrier islands was noted. It is along this coastline that 60% of the barrier islands occur which were observed along the collision margin of the Americas plate. It is here that width of the low-relief coastal zone averages 56 km, considerably broader than almost any other portion of the coastal zone along the western coast of the Americas.

A third area where an anomalously high percentage of barrier islands occurs immediately adjacent to a broad, low relief coastal plain is that of the mainland Mexico coast of the Neo-trailing margins of Gulf of California. It is here that it is possible to firmly test the hypothesis linking barrier island abundance and the geomorphic character of the adjacent coastal plain. Barrier islands are, on average, a minor portion of any Neo-trailing margins as shown in table 1. However, McGill (1958) shows that all of the barrier islands present along the coasts of the Gulf of California lie along the mainland Mexico edge. Here, from Mazatlan to the south edge of the Colorado delta at Punto Penasco, the low-lying (less than 200 m above sea level) coastal region is 50–70 km wide. Along the Baja California coast facing the Gulf of California, widths of the land area less than 200 m above sea level are 5–10 km. No barrier islands occur there.

IMPLICATIONS OF LINK BETWEEN BARRIER ISLAND ABUNDANCE AND COASTAL PLAIN CHARACTER TO GENESIS DEBATE

Shelf gradient alone does not govern the steepness of the shoreface although there is an apparent relation between width, gradient, relief and materials of the coastal region and the shoreface response to near-shore processes. Part of the response of the shoreface includes development and maintenance of barrier islands. From the data presented in this paper, it is reasonable to suggest that two general categories of barrier islands exist and that development of either type is a function of the combined character of the inner shelf and coastal plain. Both materials and width-gradient are factors governing barrier island development and maintenance.

In his discussion of barrier island genesis, Swift (1975, p. 14–19) evaluated in some detail the two previously debated ways in which barrier islands develop—mainland beach detachment and coastwise spit progradation. According to Swift, mainland beach detachment appears to be favored by low relief coastal zones. Coastwise spit progradation influences the extension of barrier islands by littoral processes, but, as an initiating mechanism, it develops along relatively steep coasts. Extending Swift's reasoning to its logical conclusion, barrier islands built primarily by coastwise spit progradation can proceed only within narrow limits of rising sea level before being overwhelmed in deeper water of estuary or bay mouths. This process is not one which could readily result in the parallelism between shoal retreat massifs and the present shoreline as observed in the middle Atlantic Bight by Duane and others (1972), Swift and others (1972), and discussed by Field and Duane (1976). Such features appear to document the continuing "remaking" of barrier islands along coasts of low relief such as along the eastern margin of the middle and southern United States.

At present, the writer is not aware of any attempt to examine barrier islands to determine whether those formed principally by coastwise spit progradation can be distinguished from those developed through processes of mainland beach detachment. Geomorphology of the inner shelf along with stratigraphy of the inner shelf and barrier islands themselves are the principal means of detecting predominance of either process. If, indeed, discrimination of these two categories of barrier islands is possible, an important step would be taken in understanding the dual modes of barrier island origins suggested by Schwartz (1971). In terms of these two categories of barrier islands, it can be presumed that the broad, low gradient continental shelves and their associated low relief coastal plains common to trailing margins would contain barrier island systems formed mainly by mainland beach detachment. Those more scattered barrier islands along steeper coastal regions, such as along coasts of collision margins, probably have been formed principally by coastwise spit progradation and not by continuous "remaking" by the tank-tread mechanism of roll-over in response to sea level rise.

At a more specific level of observation, determination of which of these two processes dominates is clearly a function of local character of the adjacent coastal lands as well as the width and gradient of the continental shelf. Thus, following these implications to their logical conclusions, barrier islands along steep coasts having little or no coastal plain probably are the product of coastwise spit progradation and thus are present day, short-lived features of those coastlines.

In contrast, the extensive chains of barrier islands along wide, low gradient coasts having an associated low relief coastal plain formed by mainland beach detachment are longer-lived features of these coastal zones. Here, the "tank-tread" landward migration can occur, resulting in the landward and upward translation of barrier island systems along the paths conceived by Field and Duane (1976).

Testing of this hypothesis that both "types" of barrier islands can occur requires stratigraphic information from both steep and low gradient continental shelves. Field and Duane (1976, p. 697) describe evidence on the Central Atlantic shelf of barrier island remnants. Steeper shelves probably lack the preserved record of partially reworked barrier island systems formed during transgression.

A second means of testing this hypothesis requires a close examination of the geomorphology of barrier islands along steep and low gradient coasts to determine whether there are unique physical features which characterize the lagoon-headland-barrier island areas of each type. This would permit recognition and differentiation of mainland beach detachment barrier islands from barrier islands formed principally by processes of coastwise spit progradation.

SUMMARY AND CONCLUSIONS

Suggestions by previous workers that shelf gradient and sediment supply are two important factors governing barrier island abundance holds well for coastlines of trailing plate margins but fails to explain abundances for other tectonic types of coastlines. It is shown here that about 75% of those barrier islands formed along trailing margins occur along coasts of Amero-trailing edges; 19.5%, along Afro-trailing margins; and, only 5.6%, along Neo-trailing margins. However, it is shown that factors governing barrier island abundance along collision margin coasts and shorelines of continents facing marginal seas are not shelf gradient and/or sediment supply. It is evident from the data presented, that a third factor, also a function of tectonic setting of the continent margin, may be decisive in determining the extent to which barrier islands line the coastal margin—that is, broad low gradient coastal plains. Where barrier islands are most numerous the adjoining coastal plains contain abundant unconsolidated and semi-consolidated detrital sediments. These sediments along with those of the inner shelf represent the immediate sediment source for barrier island development. River-derived materials clearly are not a principal source today. However, the coastal plain-continental shelf sediment prism has been the product of fluvial build-up by means of earlier regression along trailing continent margins. This prism of unconsolidated and semi-consolidated detritus characterizes trailing margins but is not a product of the tectonic evolution of coastlines of continents facing marginal seas nor of collision margins.

In the absence of this continent-margin prism of unconsolidated and semi-consolidated material, barrier island development are less common and extensive. It appears probable that the bulk of those barrier islands present along marginal sea and collision margin coastlines of continents are related mainly to present-day headland erosion and coastwise spit progradation. The absence of the semi-consolidated sediment supply available to shoreface processes prevents the "remaking" of barrier islands as sea level rises. In the most simple-minded terms, barrier islands along marginal sea and collision margin coasts are mutants in the sense that they fail to regenerate. Those along trailing margins having the coastal plain-continental shelf prism survive generation after generation as sea-level oscillates across the surface of this "infinite" supply of detritus.

It is thus suggested that geomorphology and patterns of change should be reexamined for barrier islands along coasts having little or no coastal plain. At present, there are no known criteria with which to distinguish barrier islands formed mainly by the process of coastwise spit progradation from those fundamentally resulting from mainland beach detachment.

Coastline Type	Percent of coastline lnth occupied by barrier islands	Percent of total lnth of bar. isl. along each tectonic type of coast-line (i.e., trailing, collision, marginal)	Percent of bar. isl. where tide range > 3m	Avg shelf width (km)	Shelf gradient (m/km) using 200m as shelf break
TRAILING MARGINS		48.4			
AMERO-TRAILING MARGINS					
East margin of North America (south tip of Florida to north tip of Labrador)	26.9	21.5	0.26	125.3 (104)*	1.6
East margin of South America (southeast border of Venezuela to tip of Argentina)	4.8	6.3	0.15	234.8 (120)	.85
Western Canada and United States (Arctic Sea)Ocean)	37.9	7.5	0	102.5 (68)	1.9
Eurasian landmass (Arctic Ocean)	10.7	10.7	0	1863.8 (183)	.11
Norway (Arctic Ocean and North Sea)	0	0	0	63.7 (41)	3.1
Sweden and Finland (Baltic Sea)	0	0	0	∞	
U.S.S.R., Poland, and Germany (Baltic Sea)	19.3	4.4	0	∞	
Denmark, Germany, and Holland (North Sea)	23.8	4.0	0	438.9 (13)	.45
British Isles	6.4	2.8	0.51	486.4 (40)	.41
South and west margins of Australia	8.5	5.3	0	162.0 (90)	1.2
Bangladesh, India, and Pakistan	17.1	4.9	0.17	140.3 (59)	1.4
	Sum	67.4	1.09	348 Avg	.57 Avg

Afro-Trailing Margins					
Africa facing Atlantic	7.5	19.0	0.73	78.7 (166)	2.5 Atlantic O.
Africa facing Indian	5.1			52.9 (94)	3.8 Indian O.
Africa (Mediterranean Sea)	28.9	4.9	0	44.1 (60)	4.5
Western France and Northern Spain (Atlantic Ocean)	10.9	1.3	0.69	136.2 (36)	1.5
Greenland	0	0	0	113.7 (203)	1.8
Saudi Arabia (north coast), Iraq, and Kuwait	8.2	0.9	0	∞	
	Sum	26.1	1.43	85 Avg	2.4 Avg
Neo-Trailing Margins					
Northeast Coast of Africa and southwest Coast of Saudi Arabia	2.6	0.3	0	40.7 (80)	4.9
Southeast coast of Saudi Arabia (Indian Ocean)	0	0	0	19.2 (39)	10.4
Coastlines of Gulf of California	23.4	5.7	0.63	43.3 (22)	4.6
	Sum	6.5	0.63	34 Avg	5.9 Avg
Collision Margins		22.8			
Collision Coastlines of Continents					
Alaska, Canada, United States, and Mexico (to south tip of Baja California—Pacific Ocean)	8.9	17.0	0.26	111.2 (103)	1.8
Mainland Mexico (south of Gulf of California) to south tip of Argentina (Pacific Ocean)	16.5	32.0	2.06 (all in Central America)	73.7 (188)	2.7

(Continued overleaf)

Coastline Type	Percent of coastline lnth occupied by barrier islands	Percent of total lnth of bar. isl. along each tectonic type of coastline (i.e., trailing, collision, marginal)	Percent of bar. isl. where tide range > 3m	Avg shelf width (km)	Shelf gradient (m/km) using 200m as shelf break
Southeast edge of Panama to southeast Venezuela (Caribbean)	8.9	4.8	0	67.9 (29)	2.9
Australia (east margin)	12.3	7.3	0	176.4 (44)	1.1
Eastern margin of Kamchatka Peninsula (Pacific Ocean)	0	0	0	74.5 (16)	2.7
Pakistan and Burma	0	0	0	136.6 (16)	1.5
Iran and Bangladesh	4.4	1.5	0	26.5 (27)	7.5
Northeast margin of Saudi Arabia	0	0	0	8.3 (15)	24.0
Northwest Africa (Atlantic and Mediterranean coasts)	10.9	2.7	0	17.3 (54)	11.6
Southern Europe and Middle East (to just east of Nile Delta—Mediterranean Sea)	12.7	20.9	0	60.4 (143)	3.3
Spain and Portugal (Atlantic Ocean)	22.1	3.8	0	39.2 (26)	5.1
		Sum 90.0	2.32	72 Avg	2.7 Avg
Coastlines of Trench Sides of Island Arcs					
New Guinea	4.3	2.3	0	92.4 (28)	2.2
New Zealand (North Island)	3.3	1.6	0	7.5 (20)	26.6
Taiwan	7.8	0.7	0	23.3 (10)	8.6

Japan	9.5	5.4	0	89.9 (52)	2.2
Dominican Republic—Haiti	0	0	0	7.7 (22)	26.0
Antillean chain (excluding Dominican Republic and Haiti)	0	0	0	**	**
Sumatra, Indonesia, and Celebes	0	0	0	**	**
New Hebrides and New Caledonia	0	0	0	**	**
Solomon Islands and Bismark Arch.	0	0	0	**	**
Phillipines	0	0	0	**	**
Ryukus	0	0	0	**	**
Kurils	0	0	0	**	**
Aleutians	0	0	0	**	**
	Sum	10.0	0	44 Avg	4.5 Avg
MARGINAL SEAS		28.9			
COASTLINES OF CONTINENTS					
United States (south tip of Florida), Mexico and Central America to southeast border of Panama (Gulf of Mexico and Caribbean)	38.9	46.2	0	109.1 (80)	1.8
Alaska (Bering Sea)	20.2	11.2	0.19	1278.3 (14)	0.2
U.S.S.R. (Bering Sea)	43.2	12.2	0	98.8 (33)	2.02
U.S.S.R. (Sea of Japan and Sea of Okhotsk)	7.0	6.4	0.97	202.5 (57)	0.99
Korea (Yellow Sea and Pacific Ocean)	2.3	0.7	0	171.7 (17)	1.2
China	0	0	0	394.7 (27)	0.5
Malaya, Cambodia, and Vietnam (Pacific Ocean)	18.2	7.8	0	340.6 (25)	0.6
Burma, Thailand, and Malay (Indian Ocean)	0	0	0	227.8 (17)	0.9
Northwest and northeast coasts of Australia	1.1	0.9	0.16	254.4 (28)	0.8
	Sum	85.4	1.32	342 Avg	.58 Avg

(*Continued overleaf*)

Coastline Type	Percent of coastline lnth occupied by barrier islands	Percent of total lnth of bar. isl. along each tectonic type of coastline (i.e., trailing, collision, marginal)	Percent of bar.isl. where tide range > 3m	Avg shelf width (km)	Shelf gradient (m/km) using 200m as shelf break
COASTLINES OF ISLAND ARCS					
New Guinea	2.2	1.1	0	133.2 (22)	1.5
New Zealand	12.6	4.2	0	163.2 (35)	1.2
Taiwan	25.2	2.9	0.23	∞	
Japan	14.0	5.7	0	100.8 (33)	1.98
Dominican Republic—Haiti	9.1	0.7	0	23.7 (20)	8.4
Antillean chain (excluding Dominican Republic—Haiti)	0	0	0	**	**
Sumatra, Indonesia, and Celebes	0	0	0	**	**
New Hebrides and New Caledonia	0	0	0	**	**
Solomon Islands and Bismark Arch.	0	0	0	**	**
Phillipines	0	0	0	**	**
Ryukus	0	0	0	**	**
Kurils	0	0	0	**	**
Aleutians	0	0	0	**	**
	Sum	14.6	0.23	105 Avg	1.9 Avg

NOTE.—* Number in parenthesis beneath each average shelf width is number of measurements made for each coastline segment.
** Shelf width not determined.
∞ Sea floor depth less than 200m.

ACKNOWLEDGMENTS.—Ideas in this paper were critically evaluated by Orrin H. Pilkey. The manuscript received careful critical review from Donald J. P. Swift and Paul D. Komar. Stanley Gedzelman of City College set up the statistical tests.

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