The Question of “Zonality” in Coastal Geomorphology — With Tentative Application Along the East Coast of the USA

D. Kelletat

Department of Physiogeography
University of Essen
4300 Essen 1
Federal Republic of Germany

ABSTRACT


This study investigates the zonality of modern coastal processes along a meridional profile from Florida to New York. The purpose of this research was to determine the dominant processes of coastal development, as inferred from inherent zonal qualities. Among them are coastal protection by poorly developed coral reefs, sedimentary tidal flats with mangroves, hypersaline claypans, biogenous rock forming organisms (vermetids, oysters or sabellariae) in sublittoral positions, sediment fixing calcareous algae or sea grasses, bioerosion, beachrock, and solianite. The polar limits of the oyster zone and the southern limit of coarse shelly beaches and kelp beds are important features that influence processes of coastal development. Limiting factors of these distribution patterns are briefly discussed. For the east coast of the United States, a variety of different but spatially related zonal features are delineated, viz. sea-ice cover and mangrove distribution patterns.

ADDITIONAL INDEX WORDS: Coral reefs, mangroves, bioconstruction, bioerosion, vermetids, sabellariae, beachrock, kelp beds, sea-ice, hypersaline claypans, oyster reefs.

INTRODUCTION: SOME PRINCIPLES AND PROBLEMS OF COASTAL ZONALITY

Researchers investigating aspects of relief analysis recognized decades ago that terrestrial forms (e.g. drumlins, patterned ground, braided rivers, cockpit karst, etc.) or processes (e.g. frost action, chemical deep weathering, wind transport, etc.) depend on climatic conditions. Hundreds of reports related to this general topic are published each year. They show distribution patterns with adaptations to climatic belts or to geographical regions that parallel latitudinal zonations. This concept of zonality is widely accepted today for terrestrial or sub-aerial relief and is presented (commonly in world maps) in textbooks of geomorphology and geography.

A similar “zonality” in coastal geomorphology (a concept different from “coastal zones” = parallel to the coastline: or “zonation” = from sublittoral to supralittoral positions) is not well developed or, indeed, only found in rudimentary form. Previous considerations of coastal zonality (e.g. GUILCHER, 1952, 1979; JENNINGS, 1964; DIONNE, 1976, 1981 and BIRD, 1984 among others) or attempts at development of a total concept (E.G. AUFRERE, 1936; PANZER, 1952; VALENTIN, 1982 and LYMAREV, 1966, among others) fell short of anticipated goals.

Additional efforts in the search for suitable criteria of coastal zonality (forms or processes) have initially been presented by VALENTIN (1979), ELLENBERG (1980, 1983), and KELLETAT (1979, 1982, 1985a-d). These workers were at least partly influenced by DAVIES’ concepts of “Geographical Variation in Coastal Development” (1972, 1977), observations based on a wide range of coastal phenomena in respect to their zonal or azonal character. His small-scale world maps (verified from independent sources) show that such important coastal processes as tides (particularly tidal range), currents, longshore drift, sea-level changes, and

87057 received 20 November 1987; accepted in revision 20 August 1988.
mechanical abrasion don’t have marked latitudinal orientation, while others (e.g. surf energy and wind, character of coastal sediments) are apparently related to atmospheric circulation or dominant (zonal) weathering processes on the mainland. In contrast to this observation, a third group of coastal processes such as thermoabrasion, frost action, influence of sea ice, or coral reef construction are strictly zonal phenomena.

In order to avoid confusion associated with the consideration of polygenetic forms or those with inherited characteristics derived from drowning of terrestrial relief (e.g. riatypes, fjords, vallone-coasts, inselberg archipels) or from former episodes of weathering it is prudent to first consider modern coastal processes, i.e. not exceeding the Younger Holocene with a sea-level position similar to that of today. Because the study of coastal processes and their quantification needs repeated investigation, an initial approach would be to look for phenomena that are representative of certain processes, as e.g.: living coral reefs (large scale bioconstruction); oyster banks, algal rims, vermetid trotoirs (small scale but distinctive bioconstruction, dominating bioerosion or abrasion at the same places); notches, benches, or perforations (bioerosion); mangroves (deposition, protection, progradation); tidal flats or marshes (deposition and progradation); stands of larger brown algae; beachrocks, and so on.

It is evident that such criteria should be evaluated to ascertain whether they (or others) are suitable for the determination of the “zonality of contemporary coastal processes”. Sometimes their recognition is not proof of a distinct coastal process, e.g. bioerosion in a living coral reef; disintegration of rocks by large shifting algae. For others the zonal character or climatic conditions of their appearance and distribution limits may not be clearly defined. Because of these uncertainties, this study should be regarded as provisional, at least in part. More comprehensive general and regional studies are required to further establish concepts of “coastal zonality”.

Discussion of the question of “zonal” in coastal geomorphology is needed to (1) prove whether there are important or dominant zonal influences or whether azonal (ubiquous) phenomena are more widespread; (2) consider the ecological and biogenetic conditions which influence coastal forms or to distinguish qualitatively/quantitatively which is the main modern process (e.g. hard algal or vermetid covers at rocky coasts); (3) learn more about the (climatic) control of distribution and limits of certain phenomena (e.g. beachrocks, eolianites, bioerosion, etc.); and (4) compare modern coastal zones with those of prior sea-level conditions or former climates.

The aim of this study is not to test concepts of coastal zonality in detail for the USA, but to initiate discussion. The author has already discussed “coastal zonality” in two different ways by investigating profiles over a wide range of latitudes (to define zonal limits) and by special mapping and detailed studies within selected coastal zones to determine which (if any) processes are bound to specific zonal environments (KELLETT, 1979, 1982, 1985b, c, 1986, 1987; KAYAN et al., 1985; KELLETT and SEEHOF, 1986). Thus, some preliminary ideas have been developed for coastal zonality in Europe, the Mediterranean, Eastern Australia, and New Zealand.

Comparison of conditions on both sides of the North Atlantic ocean could be beneficial to studies of coastal zonality. The vast coastal literature (nearly 1500 titles since 1960) for the region extending from Florida to Maine provides an adequate research base for that purpose, see e.g. regional studies of TUTTLE (1960), JOHNSON (1961), BLOOM (1967), HAYES et al. (1969), PANUZIO (1969), MEADE (1971), HAYES (1972), and many others, studies of widespread coastal wetlands and marshes (e.g. ADAMS, 1963; SPACKMAN, DOLSEN and RIEGEL, 1964; SCHOLL, 1966; WASS and WRIGHT, 1969; ANDERSON, CARTER and McGINNIES, 1973; CHAPMAN, 1974; SILVERHORN, DAVIS, 1974; HALVERSON and GARDINER, 1977; REIMOLD, 1977; BROWN, 1978; CLEARY, HOSIER and WELLS, 1979; KAYAN and KRAFT, 1979); those on barrier islands (DOLAN, 1973; DOLAN et al., 1977; BAGUR, 1978; DOLAN, HAYDEN and JONES, 1979; GODFREY, LEATHERMAN and ZAREMBA, 1979; KOCHEL et al., 1983; LEATHERMAN, 1983); or the more general studies of DOLAN et al. (1973), HAYDEN and DOLAN (1977, 1979), or TANNER (1960).

Although comparative studies of coastal zonality for the east coast of the USA were largely
lacking until recently, there is a very good knowledge pool consisting of excellent maps, aerial photographs or satellite images (for the whole region) which makes it one of the best documented coastlines in the world. The author’s field work in this region (i.e. from 24°30’N to 44°N) in the spring of 1985 was cursory and cannot substitute for detailed research activities. Nevertheless, it is still possible to present some rough outlines of coastal zonality in that section. Because of the sedimentary character of the coast (except in northern parts) the scope of discussion is narrowed mostly to criteria that apply to non-rocky (soft) coasts. Because of complicated environmental conditions peripheral to the topics, the zonality of Florida’s eastern coastline is discussed in greater detail. Some climatic and hydroclimatic dates (as a background for orientation) are presented in Figure 1.

SOME OBSERVATIONS AT THE COASTS OF EASTERN FLORIDA

Climatologically, Florida is the only region of the North American mainland that is subtropical. Besides the Arctic and Antarctic, the zonal character of this littoral region (with its coral reefs and mangrove tidal flats) has long been recognized. It thus seems useful to re-evaluate the zonality of the east coast of Florida.

Bioconstruction by Coral Reefs

Only the extreme southern reaches of Florida (south of Miami) are part of the coral reef zone. However, the reefs are mainly limited to the SE and S of the Florida Keys and are disintegrated into single complexes of limited aerial extent and are by no means comparable to other fringing reefs that thrive elsewhere.

As seen in Figure 1 the Florida coral reefs don’t fill the area of potential distribution, the northern limit of which is defined by the 18° C-isotherm of average minimum water temperatures in the coldest month. Even in its diminished area the number of the species, extension of reef tracts, and rate of regeneration lag behind fringing reefs in the Indian and Pacific oceans. By comparison, the northern reefs of Bermuda are more varied and richly formed. The Florida reefs are separated from the island chain of keys by some kilometers and do not advance to the low water level generally staying some meters below it. The reefs are mainly composed of debris rather than living corals. Destruction by storms or bioerosion can be observed everywhere. Most of the reef tracts have a rather monotonous appearance (Figure 2). It is also noted that the most important coastal processes affected by coral reef growth, i.e. large scale bioconstruction and/or protection of the mainland coast against wave attack, is hardly applicable to the Florida reefs.

As pointed out by Hoffmeister (1962), Ginsburg and Shinn (1964), Hoffmeister, Stockman and Multer, (1964); Greenberg and Greenberg (1972); Dodd, Hattin and Liebe (1973); Jones (1977) or Marszalek, Babashoff, Noel and Worly (1977); Shinn et al. (1977); Jameson (1981), growth of the Florida reefs is adversely affected by a variety of factors. First, there is the large amount of sediments, partly in suspension, that is carried from shallow water areas west of the keys through narrow gaps between the islands by relatively strong tidal and sea currents. These sediments consist of small calcareous algal debris, particularly Penicillus (Stockman, Ginsburg and Shinn, 1967), ooids, and other calcareous mud (see Ginsburg et al., 1964; Ball, 1967; Hoffmeister, Stockman and Multer, 1967; Stockman, Ginsburg and Shinn, 1967; Hoffmeister and Multer, 1968; Friedman, 1970; Multer, 1971b; Jindrich, 1972; Ebanks and Bubb, 1975). This mixture of sediments, particularly ooid formation, is normally bound to shallow waters with high temperatures, which are only found in tropical and subtropical environments. They therefore can be regarded as another zonal factor in coastal formation because together with dense stands of seagrass (see below) rapid sedimentation is provided by calcareous particles instead of coral growth.

Moreover, there are pronounced temperature fluctuations and salinity variations in the shallow waters of the Florida Keys (the first factor not being typical of tropical conditions). Another negative factor is the amount of freshwater seasonally flowing in from the Everglades. All these conditions impede the healing of (tropical = zonal) hurricane induced
mechanical damages; and besides them and as everywhere in the world, the reefs have to prevail against a variety of boring and pasturing organisms. So within the potential zone of reef bioconstruction this process in parts is substituted by calcareous sedimentation.

Other Biogenetic Factors of Rock Formation

Numerous littoral organisms (oysters (Crassostrea virginica in particular), vermetids (V. nigricans), and sabellaries (e.g. Phragmatopoma lapidosa or Sabellaria vulgarius)) - which are worms that live in great populations and transform sediment particles into solid living-tubes thus producing flat "hardgrounds" (see e.g. Ginsburg, 1960; Shier, 1965, 1969; Kirtley, 1966, 1974; Multer and Milliman, 1967; Gram, 1968; Kirtley and Tanner, 1969; Frost, 1974; particularly the many hardgrounds produced by them which protect the coast from erosive potential) are other important biogenetic factors in the development of Florida's coastlines. Their contribution to the production of beach, dune, and foreshore sediments is remarkable. Presenting another mineralogical content as normal beach sand, more suitable for abrasion and coastal erosion on one hand but for cementation as well on the other, they mark a special sub-zone of coastal formation in the warm environments of southeastern USA. Only a few sites are surpassed by debris of calcareous algae, foraminifers or shell fragments (Sanibel Island in the West, Ormond Beach-Daytona in the NE and elsewhere). Their precise extension can only be detected by observations under water. Due to the lack of exposed bedrock, the region does not exhibit trottours, usual for lower latitudes, nor miniature atolls (see Kell etat, 1979, 1982). Littoral organisms are thus always closely associated with the beach and situated below the low water line because the dynamic environment of the beach impedes their augmentation.

Sedimentation and Protection by Mangroves

Mangroves have a remarkably higher impact on the development of the Florida coasts than coral reefs, with their northern boundary extending to 28°N near Cape Canaveral (e.g. Welch, 1963; Spackmann, Dol sen and Rie gel, 1966; Scholl, 1969; Savage, 1972; Reimold, 1977; Stevenson, 1984). This boundary corresponds to the polar range of mangroves in other continents (Sinai, East Asia), except that Kandelia kandel extends as far as 35°N in Japan and that Avicennia marina var. resinifera can be found beyond 38°S in Australia and New Zealand. Due to the fact that mangroves tolerate marked changes of salinity and rainfall it is difficult to explain their polar extension. High temperatures and slight temperature changes are not limiting factors (see e.g. Walsh, 1971; or Ellenberg, 1980). Davis (1940, p.366) regards temperatures below 4°C as lethal to mangroves. However, the lasting and severe frosts of the winters of 1983/84 and 1984/85 that caused the death of even older citracles in wide areas of Florida did not visibly harm the mangroves.

Although widely spread (into the Everglades, Figure 3), the mangroves of Florida consist of

---

Figure 1. Boundaries of factors standing for actual forming processes in the east of the USA.
only three species. The “red” mangrove (*Rhizophora mangle*) is the most widely distributed. Its characteristic stilted roots (Figure 4) frequently seen in muddy and sandy soils, also occur in solid grounds as well. In the Florida Keys *Rhizophora* tends to grow on the exposed edges of islands (Figure 5), along tidal inlets, and around circular hollows that have been deepened by karstification of old reef debris filled with salt water. Thus, typical ribbon or circular vegetation patterns are formed. *Rhizophora mangle* is a pioneering species that ranges from exposed outer sand banks to the inner fresh-water zone of the Everglades. The “black” mangrove (*Avicennia nitida*), however, characterized by its stick-shaped respiration roots, is limited to muddy ground and stands behind the outer *Rhizophora* fringe. Its height
of up to 20 m can surpass that of *Rhizophora*. *Laguncularia racemosa* is regarded as the "white" species of the Florida mangroves. It grows from the uppermost line of the tidal range to beyond tidal influence thus forming the landward fringe of the mangroves. Because mangroves extract nutrition from water (DAVIS, 1940; WALSH, 1971; CHAPMAN, 1974), soil nutrients is less important to them than to other terrestrial plants.

Mangroves are often regarded as "land formers" because their intricate and densely mingled roots cause sediments to settle. In Florida mangroves are not the organisms that primarily contribute to sedimentation in the intertidal zone or of the littoral as a whole. More important are the numerous sublittoral calcareous algae and their sediment particles (among them *Halimeda opuntia, Jania or Amphiroa*), the sediment fixing sea grasses (*Thalassia testudinum*) and other larger inhabitants of the littoral such as oysters, vermetids, and sabellariae. Their habitation facilitates the development of sandbars to the high water line (Figures 2 and 6). These organisms are, however, susceptible to hurricane induced damage. Mangrove islands of the Ten Thousand Islands (Figure 3) and adjacent extensions of the Everglades are not the result of mangrove growth. The mangroves merely mould eulittoral extentions of the banks established by oysters in the inner and by vermetids in the outer salty areas. Their sprouts and litter, the latter forming mangrove peats, contribute little to the expansions of the islands and consequently to a gain in land area. Florida mangroves are less the formers of land than they are protectors because their solidly founded and densely intermingled root systems endure severe hurricanes. Farther inland the mangrove fringe is followed by *Salicornia*, then by *Spartina* and finally by *Juncus*. Finally, it should be noted that mangroves do not limit zones and tropical and subtropical coasts (as do coral reefs) because they extend into temperate latitudes. Nevertheless, they are a clear zonal phenomenon and mark an important zone of coastal sedimentation and protection.
Figure 5. The concave contours of the coasts of the western Sugarloaf Keys show an older karst relief, whereas the tiny mangrove islands in the foreground indicate a recent land gain in pure salt water (Aerial photograph; height: c. 800 m, range: 3.5 kms).

Features of Bioerosion

Bioerosion has often been described as a feature of lower latitude carbonate rocks. The variety of miniature forms seen as notches and “rock pools”, however, are incorrectly reported in many textbooks as the inorganic solution of limestone in the course of salt-water karstification. As observed in the eulittoral and supralittoral, the process of bioerosion is caused by the sapping of gastropods (Patellidae, Littorinids and others) on endolithic blue-green algae (cyanophyceae). Because solid rocks are missing in Florida littoral, bioerosion (except on coral reefs) is of little importance (cf. CRAIG et al., 1969; HEIN and PISK, 1975; HUDSON, 1977).

A new observation concerns cemented beach sediments in the NE of the peninsula near the “Washington Oaks Garden Area.” The little rock pools formed there by Siphonaria pectinata species are not very striking because they are exposed to heavy sand corrosion that frequently destroys them. It is only in recent years that bioerosive phenomena have been investigated in higher latitudes or cooler coastal environments (TRUDGILL, 1977, 1987; KELLETAT, 1986b, 1988) as a locally important factor. Therefore, it seems presumptive to use bioerosion as a characteristic feature that delineates a specific zone of formation before precise information on limiting factors can be worked out.

Cementation (and Coastal Protection) by Beachrock and Eolianite.

Cementation on the beach and in dunes along coasts in lower latitudes are reported worldwide (e.g. DAVIES, 1972, 1977; ELLENBERG, 1980; KELLETAT, 1975, 1979, 1985b). Whereas consolidated dunes are mostly Pleistocene in age, beachrock as an element of younger coastal formation needs to be investigated in terms of its distribution and zonality. The development of beachrock affects normal
shoreline processes because beaches formerly consisting of loose material have been changed into resistant rocky coasts. Although it is desirable to ascertain what causes the cementation of beach sands (at present this is very difficult), it is probably more practical to record beachrock distribution. Such patterns might indicate possible limiting (climatic, hydroclimatic, and biogeochemical) factors.

In comparison to other regions in similar latitudes with abundant carbonate sediments, Florida exhibits remarkably few beachrock areas. Beachrock is mostly missing, because mangroves extend to the mean water line, mud is a common sediment, and at many places beaches are undergoing rapid erosion.

Beachrocks in Florida have been described at the southern end of the Keys, in the Dry Tor-
tugas (MULTER, 1971), as well as north of Miami (GINSBURG et al., 1964; CRAIG et al., 1969). One of the outcrops of cemented beach material is presented in Figure 7 (described by KELLETAT, 1987a). It is situated NE of Ormond Beach in the "Washington Oaks Garden Recreation Area" and extends for many kilometers to St. Augustine. The beachrock reaches several meters above the mean water line and consists of coarse grains with lime spar and quartz as cements. Magnesium is missing thus disproving the young age of this sediment and its cementation.

Root casts and fossilized roots indicate that this formation is not real beachrock, but grains and stratification exclude eolianites as well. It seems to be a deposition resulting from hurricane impact, which destroyed or at least buried a standing forest. Most of the cemented sediments should be older than Holocene (Anastasia formation?) but near the water line (compare the arrow in Figure 7) a younger sediment seems to be a proper beachrock.

Compared to environmental and climatic data from beachrock and eolianite sites elsewhere (particularly the Mediterranean) this outcrop doesn't reach the potential poleward limit of eolianites or beachrocks. Alas, the observations in Florida do not contribute clearly to a definition of limiting zonal factors for beach (or coastal dune) cementation.

**ZONAL ELEMENTS ALONG THE EAST COAST OF THE USA NORTH OF FLORIDA**

From the large number of important elements of coastal dynamics (e.g. sea-level changes, tides, currents, longshore drift, marshes and tidal flat sediments, beach materials, biogeometric features of the eu- and sublittoral) a selection is made (see Figure 1) for those which represent contemporary coastal processes.

Although widespread along the coast of southeastern Florida (e.g. the Ten Thousand Islands) bioconstructional features occur fur-
ther poleward between about 30° and 35° north latitude. Besides vermetids and calcareous algae, banks, platforms and flat reeflike structures of oysters (particularly *Crassostrea virginica*) occur near the mean high water level, often in sandy or muddy environments. The northern limit of larger constructional forms seems to be defined by water temperatures lower than 10°C or air temperatures in the coldest month of about 5-7°C.

Intertidal sediments can influence coastal dynamics. The nature of these sediments is determined by relief and weathering of the mainland, or tidal range and currents and secondarily by biogenic or climatic conditions. A new coastal landscape element, primarily used to typify different mangrove tidal flats (VALENTIN, 1975; KELLETAT, 1986), is presented by hypersaline clayspans at the upper spring tide high water level. The evaporate layers are rather thin, salinity levels are too high for vegetative growth, and sedimentation seems to be lower than elsewhere in the intertidal zone. Along the US east coast the meridional as well as spatial extension of hypersaline clayspans is restricted in Georgia and South Carolina by high annual rainfalls that are seasonally well distributed. In tidal areas rarely flooded by salt water the evaporation rates are not great. The bare expanses of the salt clayspans are usually surrounded by *Juncus* and *Phragmites*, towards the sea by *Spartina alterniflora* var. *glabra* and by *Salicornia*. Already at 34°N the "arid" conditions have changed so much that these striking landscape patterns cease to develop.

Around Cape Hatteras winter temperatures of the water fall below 10°C. Therefore oxygen and nutrient contents of the coastal waters increase and large, long-living gastropods and mussels become a typical beach sediment, particularly after storms (Figure 8). Although this is a widespread phenomenon, its relevance for coastal processes is less significant and possibly result only in a slight decrease of erosive tendencies.

Northwards along the beaches and tidal flats conditions change little, except that the wind becomes stronger and coastal dunes increase both in height and extent, *i.e.* compared to Georgia and South Carolina. The high dunes provide some natural protection of coastal lowlands against flooding.

The southern border of "glacially formed coasts" that corresponds to the maximal range of the Pleistocene glaciation is of great importance to coastal configuration. The slight increase of coarser sediments in beach environments provide some protection against erosion during weaker surf conditions.

From about 42° North latitude larger algae and kelp species (*Fucus* and *Laminariae*) become morphologically important elements (see HUMM, 1969; BRADY-CAMPBELL, CAMPBELL and HARLIN, 1984). They tend to develop "kelp-beds" that remarkably reduce surf energy and erosion. Their beneficial role has just recently been indicated for subarctic Europe (KELLETAT, 1985c and d).

North of the US east coast the effects of ice and frost on the rocky littoral and beaches become increasingly apparent. They are soon followed by the morphological impact of the sea ice cover that has been described in numerous studies for the Canadian east coast by DIONNE (1981). Its border line is one of the morphologically very important ones as far as actual coastal formation, intensity of the processes, and variety of phenomena are concerned.

**SOME CONCLUSIONS**

Summarizing, the meridional profile along the east coast of North America shows zonal phenomena of very different importance with respect to coastal processes: the southern limit of regular maximum sea ice cover with impact on coastal formation (*i.e.* pushed boulders, grooves, and kettle holes in tidal mud flats, boulder barricades at the seaward margin of tidal areas *etc.* ) is one of significance in the north, followed by the boundary of large kelp species, while other features (*e.g.* sedimentation of evaporites in hypersaline tidal flats) are of minor importance. In the southeast hardground constructing (and protecting) species such as oysters, accompanied southward more and more by calcareous algae, vermetids and sabellariae, influence formative processes which are greater than those of small and singular coral reefs. The dense mangrove stands, which at the same time protect the coastline against storms and accelerate tidal sedimentation, are an important factor in the south. These growths are also accompanied by the production of large amounts of lime sediment (debris of calcareous algae or ooids) are addi-
Figure 8. Numerous and thick shelly fragments as part of beach sediments after stormy conditions at Atlantic City, New Jersey

tionally stabilized by seagrass below the mangrove rooting level.

It seems difficult to determine the boundary between tropical and extratropical conditions along this profile because the only good indicator for tropical coastal zones, i.e. coral reefs, are poorly developed or degraded and do not extend to their potential poleward distribution. On the other hand, mangroves generally can not be used as indicators for tropical (or subtropical) coastal conditions (though in eastern Florida they end near the border of the tropics or at the potential limit of coral reef distribution marked by the 18°C-isotherm of coastal waters in winter), because they occur (in other continents) in regions of temperate climates with regular frost and summer temperature averages below 20°C (e.g. in southeastern Australia and northern New Zealand).

To conclude, the east coast of North America is an example of a latitudinally compressed sequence of different coastal forming conditions that comprise 20 latitudinal degrees between regular sea ice cover and mangroves. Along the opposite European/African coast of the Atlantic the same sequence is expanded to 45 degrees of latitude.

ACKNOWLEDGEMENTS

The author wishes to thank the referees for useful suggestions and Charles W. Finkl for the revision of the English text.

LITERATURE CITED


BAGUR, J. D., 1978. Barrier Islands of the Atlantic


Coast Research Group, University of Massachusetts, Contribution, 1, 462p.


HÖFFMEISTER, J. E., 1962. The coral reef limestone factory. Sea Frontiers, 8(4), 213-218


KIRTLING, D. W., 1966. Intertidal reefs of Sabellariidae (Annelida polychaeta) along the coasts of Florida. Coastal Research Notes, Florida State University, Tallahassee, Florida, 2, 3-7


LYMAREV, V. I., 1966. K voprosu o zool'nosti beregovych processov i tipov beregov. Vestnik Leninogradskogo univ., 6, Ser. geol. i geogr., 1, 88-100


☐ ZUSAMMENFASSUNG ☐

etlicher zonaler Erscheinungen, obwohl nahezu ausschließlich Lockermaterialküsten vorkommen. Zwischen der Zone regelmäßiger Meereisbedeckung und der der Mangroven liegen hier weniger als 20 Breitengrade, während für die gleiche Spannweite der küstenmorphologisch wichtigen Phänomene im europäisch-vorderasiatischen Meridionalprofil mehr als 45 Breitengrade überspannt werden müssen.