for a homogeneous Moon. He also deduces, from geophysical arguments, that Moon is slightly denser toward the center—sufficiently so to reduce these values by about 1 percent. He bases his numbers on lunar libration theory rather than on lunar orbit theory which in its present state requires much greater value (in absolute magnitude) of C_{20}, corresponding to a Moon with crust denser than interior (*5*). The value of C_{20} obtained by us from Lunar Orbiter data is some 3 percent less in magnitude than the homogeneous-Moon value and thus corresponds to a Moon having an interior density moderately higher than crust density. Tolson and Gapcynski (*6*, *7*) and Michael *et al.* (*7*) derive somewhat different results from some preliminary reductions of these data—although an almost homogenous Moon is implied, as we infer. (Michael *et al.* used a direct fit to the raw data, whereas we used the method of averages for the reduction.) Thus more data must be analyzed before consistent solutions are obtained.

Table 1. Preliminary estimates of lunar-gravity harmonics, based on Lunar Orbiters I–IV. Normalization factor:

$$\{[(n-m)!/(n+m)!](2n+1)\ (2-\delta_0{}^m)\}^{\frac{1}{2}}$$

Harmonic coefficient	Coefficient values (× 10⁴)		S.D. (σ × 10⁴)	
	Not normalized	Normalized	Not normalized	Normalized
C_{20}	−2.0263	−0.9062	0.0143	0.0064
C_{21}	−0.0878	− .0680	.0131	.0101
C_{22}	0.2191	0.3394	.0249	.0386
C_{30}	−0.2223	−0.0840	.0262	.0100
C_{31}	0.3636	0.3366	.0025	.0023
C_{32}	−0.0257	−0.0752	.0058	.0170
C_{33}	− .0265	− .1900	.0079	.0567
C_{40}	0.0941	0.0314	.0190	.0063
C_{41}	−0.1236	−0.1303	.0046	.0049
C_{42}	0.0361	0.1614	.0034	.0152
C_{43}	.0164	.2747	.0021	.0351
C_{44}	.0091	.4313	.0011	.0521
C_{50}	−0.1614	−0.0487	.0321	.0097
C_{60}	− .1089	− .0302	.0121	.0034
C_{70}	0.1734	0.0448	.0122	.0031
C_{80}	−0.2011	−0.0488	.0114	.0028
S_{21}	0.0150	0.0116	.0139	.0108
S_{22}	.1310	.2029	.0335	.0519
S_{31}	.0740	.0685	.0032	.0029
S_{32}	−0.0200	−0.0586	.0063	.0184
S_{33}	− .0496	− .3557	.0114	.0818
S_{41}	0.0564	0.0595	.0051	.0054
S_{42}	.0051	.0228	.0035	.0157
S_{43}	−0.0276	−0.4618	.0015	.0251
S_{44}	0.0079	0.3739	.0011	.0521

Table 2. Pairs of coefficients with correlations greater than 0.8.

Pair	Correlation
C_{20} and C_{40}	+.94
C_{20} and C_{60}	+.82
S_{21} and S_{41}	+.81
C_{30} and C_{50}	+.97
S_{32} and C_{42}	−.91
C_{32} and S_{42}	+.87
S_{33} and C_{43}	−.86
C_{40} and C_{60}	+.84
C_{50} and C_{70}	+.86

For the odd zonals, we have no nonorbiter values for comparison. These coefficients describe the north-south asymmetry, sometimes referred to as the pear-shape. Akim (*8*) has published a value of C_{30}, based on a Russian orbiter, equal to -0.363×10^{-4}, which is somewhat larger numerically than ours, but of the same sign.

Table 2 lists the pairs of coefficients having high correlations. Of course the values of the correlations are completely dependent on the types of orbits from which the data were taken; a more complete set of orbits would yield data giving smaller correlations.

We must emphasize that these results are preliminary; the data are still being refined and, we hope, will submit to better fits. Furthermore, more data should soon become available from Lunar Orbiter V.

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5 October 1967

Crescentic Landforms along the Atlantic Coast of the United States

Abstract. *An uninterrupted series of hierarchically arranged crescentic coastal landforms occurs along the Atlantic coast. Dimensional analysis suggests a geometric relation between order, amplitude, and number. The processes responsible for these features also may be continuous in nature.*

Crescent-shaped sand ridges with their concave sides facing the sea are among the most frequently observed landforms in coastal areas composed of sedimentary materials. Among the smallest of these forms is the beach cusplet, measuring about 1.5 m between tips of the crescent. Even the casual visitor is familiar with these swash-zone features (Fig. 1a) and is aware that their life-spans are short: usually they appear and disappear with the turn of the tide. More common are the larger, typical beach cusps which range from about 8 to 25 m from apex to apex (Fig. 1b); they usually develop by erosion of the seaward faces of depositional beach ridges during fair weather, and have life-spans measurable in days. Still-larger crescentic forms are relatively common, including Evans's (*1*) "storm cusps," which measure from 70 to 120 m and develop during periods of relatively heavy seas. Shepard's (*2*) "giant cusps," also known as shoreline rhythms or migrating sand waves (*3*), range in size from 700 to 1500 m and appear to be characteristic of areas or times of relatively strong littoral currents (Fig. 1c).

During investigations of shoreline processes along the coast of North Carolina, two attributes of these cuspate features were observed: (i) they seem to be hierarchically arranged—smaller features are grouped within larger ones; and (ii) a tendency toward clustering by size; Fig. 2 shows the size-frequency distribution of about 750 cuspate features along the Outer Banks of North Carolina and the central Atlantic coast. The modes on this curve (Fig. 2) confirm the distinct hierarchical nature of these features, as well as logarithmic spacing between groups. These data are recast in Fig. 3, in which modal values for each group (called orders) are plotted as single points, and a line connecting these points is extended to cuspate forms of larger size.

Clearly the Carolina capes, measuring about 100,000 m, fall into sequential position along the projected line, and close examination of maps of the southern portion of the Atlantic coast (*4*) indicates secondary cape-like features occupying the predicted positions between rhythmic sand waves and the order of the Carolina capes (Fig. 1d). Ironically, further extrapolation yields two additional orders: one at 10^6 m, which is the approximate distance between the southern tip of Florida and Cape Hatteras; and another at 10^7 m—almost exactly 90 deg of latitude.

Our purpose is to suggest that the steady-state shoreline configuration along the southern portion of the Atlantic coast is an uninterrupted system of features, sinuous in form (*5*), geometrically similar, and reflective of long-term trends in coastal currents as well as of short-term variation in the state of the sea. The regularity or sinuosity of any segment is a measure of development from the original and transient states toward the steady state. The controls are resistance of the materials exposed along the coast, intensity of the littoral processes, and stability of the land-sea interface.

Although the geometric relation of Fig. 3 suggests that the processes responsible for crescentic coastal landforms are somehow linked, there is little quantitative evidence to establish specific process-response relations. In fact, when the full range of crescentic coastal features is considered, it appears that the processes must include both planetary ocean currents as well as waves and associated surf-zone processes.

The larger, more permanent features (order 4 and higher) may reflect regional control established by a series of secondary rotational cells that develop along the western margin of the Gulf Stream (Fig. 4). The development of these "eddy currents" was first suggested by Tuomey in 1848 (*6*), and the question of their role in the formation of the Carolina Capes was discussed by Abbe in 1895 (*7*). Although the eddy currents are too low in velocity to entrain sand-size sediment (*8*), they may play a signifi-

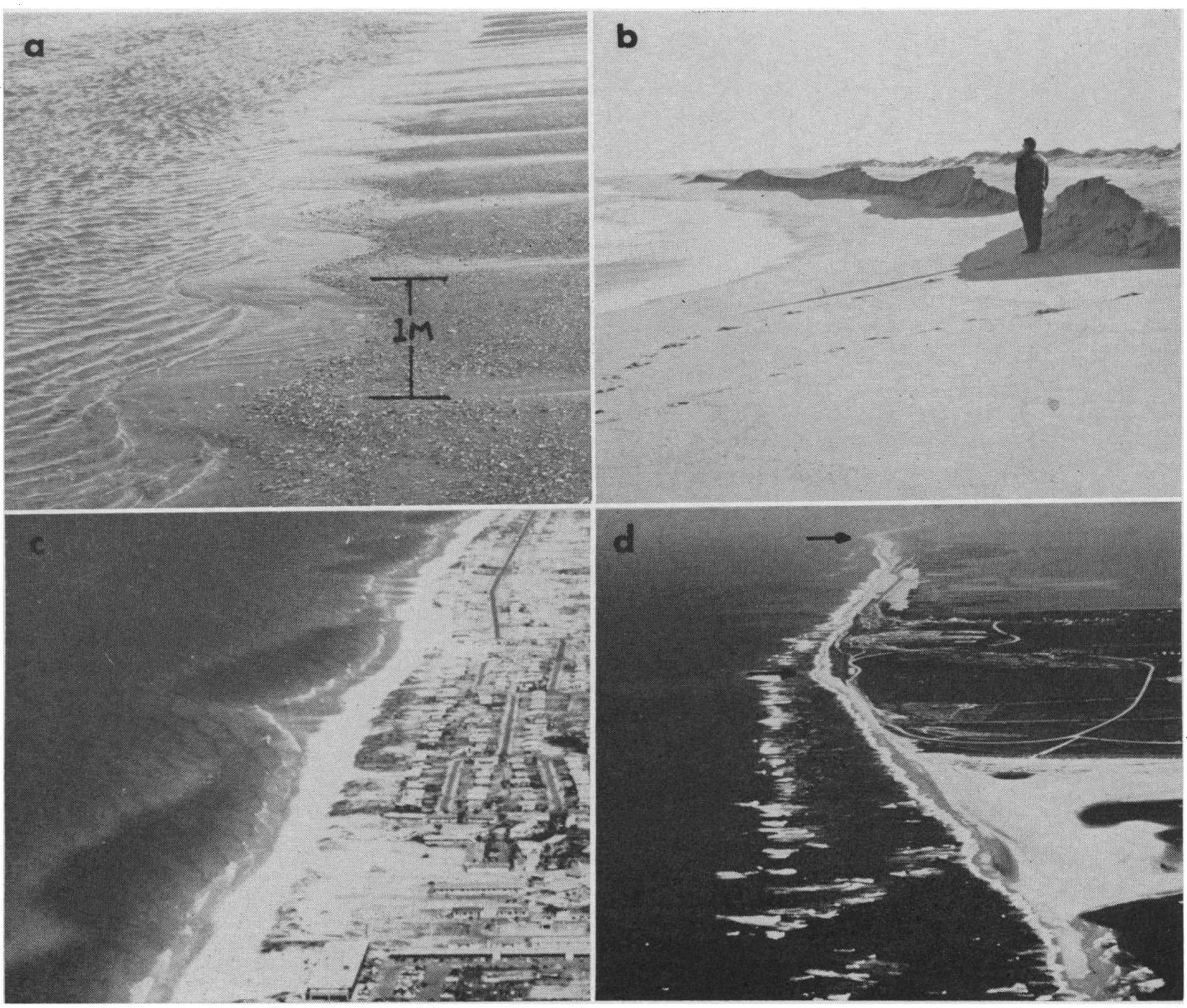

Fig. 1. (a) Swash-zone cusplets measuring about 1 m in amplitude. (b) Typical "fair-weather" beach cusps truncated by storm waves. (c) Rhythmic sand waves along the coast of Florida; note the close relation between subaerial and subaqueous morphology. (d) Cape Hatteras; two distinct "secondary cape-like features" are indicated.

cant role in the ultimate distribution of the sediment once it is placed in suspension by shoaling and breaking waves.

Superimposed on the framework of the larger, more stable forms of the system are the smaller ephemeral crescentic features distributed along the lower part of the curve (Fig. 3). Beach cusps of orders 1–3 are surely linked directly with shallow-water wave deformation and associated inshore current cells that are in turn linked with currents of the larger rhythmic features of order 4. This fact suggests a direct relation between rate-of-change and order, with the smaller features (orders 1–4) responding to seasonal and short-term variations in the state of the sea, and the larger features (orders 5 and 6) responding to the less variable controls, such as wave climate and sea level. [The transitional part of the curve (Fig. 3) appears to be between orders 4 and 5, with increased scatter in the lower orders defining the most dynamic elements of the system.]

In summary: Crescentic coastal landforms, such as the Carolina capes, represent only one order of shoreline form in an uninterrupted hierarchical grouping of coastal features. The central questions regarding the origin of these features are: (i) Do the features reflect and are they controlled by interacting processes, including both planetary currents and shoaling and breaking waves? (ii) Are these interacting processes continuous in nature?

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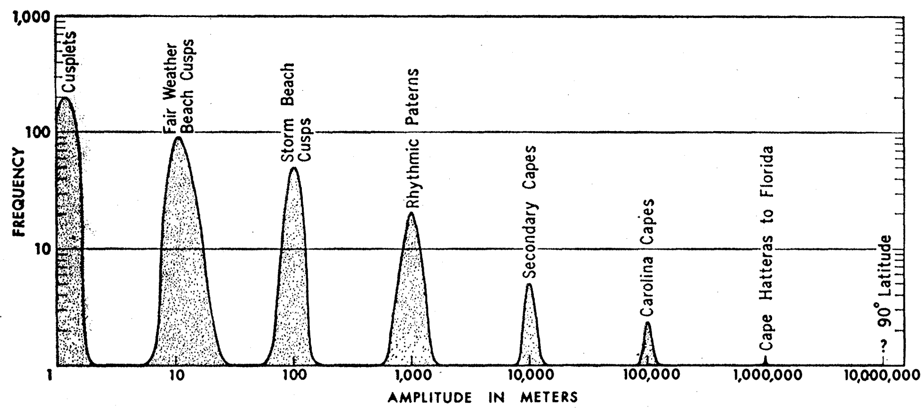
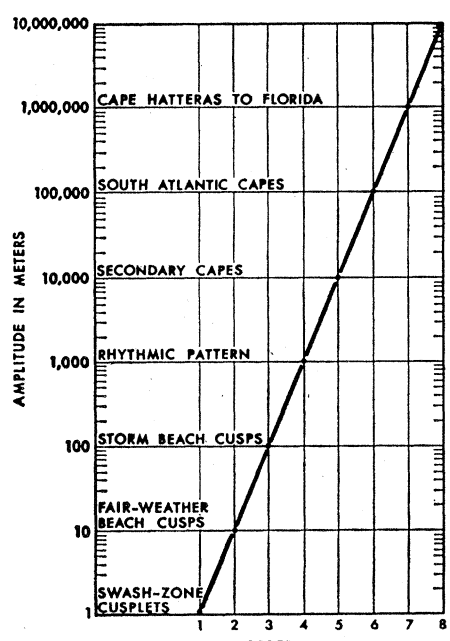


Fig. 2. Frequency and amplitude of crescentic forms observed along the middle of the Atlantic coast.



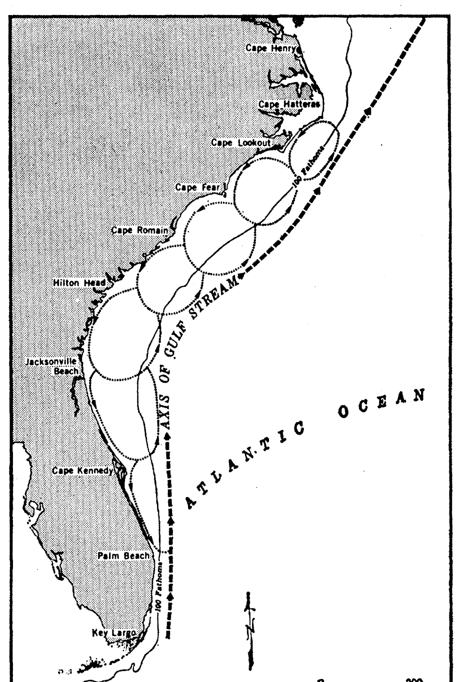


Fig. 3 (left). Relation of average amplitude to cuspate order. Fig. 4 (right). Eddy currents that may generate along the western margin of the Gulf Stream (after C. Abbe). Crescentic coastline forms may reflect steady-state configuration. The controls are: resistance of the materials exposed along the coast, intensity of the littoral processes, and stability of the land-sea interface. Thus the well-developed capes, such as Hatteras, Lookout, Fear, Romain, and Kennedy, occur in sandy regions having narrow continental shelves.

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8 November 1967

Carbon Tetrachloride: Plastic Properties

Abstract. *The shear strength of solid carbon tetrachloride was measured from 187° to 247°K. A 25-percent discontinuity was observed at the solid-solid transition, at about 225°K. This transition exhibited a distinct hysteresis. The shear strength of both the high- and low-temperature forms increased very rapidly as the temperature was lowered. There was no evidence of a rhombohedral high-temperature phase.*

Carbon tetrachloride exhibits an interesting variety of polymorphic transformations in the solid state. The liquid freezes at 250.5°K to form a face-centered-cubic plastic crystal characterized by a low strength and high ductility. Plastic crystals are also typified by several other features such as globular molecules, a low entropy of fusion, and a high degree of molecu-