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Retro-action model for the formation of irregular or fractal rocky coasts. Are irregular breakwaters more efficient ?

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Rocky coasts are estimated to represent 75% of the world’s shorelines [1]. We discuss various situations where the formation of rocky coast morphology could be attributed to the retroaction of the coast morphology on the erosive power of the see. In the case of rocky coasts, erosion can spontaneously create irregular seashores. But, in turn, the geometrical irregularity participates to the damping of sea-waves, decreasing the average wave amplitude and erosive power. There may then exist a mutual self-stabilization of the waves amplitude together with the irregular morphology of the coast. A simple model of such stabilization is discussed. It leads, through a complex dynamics of the earth-sea interface, to the spontaneous appearance of an irregular sea-shore. The final coast morphology is found to depend on the morphology/damping coupling of the coast and on the possible existence of built-in correlations within the coast lithologic properties. This is illustrated in the figure.
In the limit case where the morphology/damping coupling is weak and when the earth lithology distribution exhibit only short range correlations, the process spontaneously build fractal morphologies with a dimension close to $4/3$ [2]. This dimension refers to the dimension of the so-called accessible perimeter in gradient percolation. However, even rugged but non-fractal sea-coasts morphology may emerge for strong damping or during the erosion process. When the distributions of the lithologies exhibit long range correlations, a variety of complex morphologies are obtained which mimics observed coastline complexity, well beyond simple fractality.
On a somewhat different perspective, the design of breakwaters is suggested to be improved by using global irregular geometry with features sizes of the order of the wave-length of the sea oscillations.

[1] R. A. Davis, Jr, D. M. Fitzgerald, Beaches and Coasts,(Blackwell, Oxford 2004).
[2] B. Sapoval, A. Baldassarri, A. Gabrielli, Self-stabilized Fractality of Sea-coasts through Erosion, Phys. Rev. Lett. 93, 098501 (2004).