



The geomorphology of Mediterranean Coasts: Imbrication of natural and human-induced driving forces over the last five thousand years

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The present geomorphology of the shores of the Mediterranean perfectly illustrates the intricate relationship between Nature and Humans. The tectonic context, comprising both active and passive margins and notable seismicity, and the climate, have resulted in a highly diversified coastal morphology and a sediment-supply regime that has been often very active, generating numerous fertile deltas. Cradle of ancient civilizations, the Mediterranean has seen its shores occupied by Humans since antiquity. The attractiveness of these shores, highlighted by the position of the Mediterranean as the world's leading tourism and leisure destination, has considerably reinforced this situation, on which will also depend the future of the Mediterranean. Expressions of this relationship between Nature and Humans are diverse and affect all types of shores.

Leaving aside the potential influence of the Neolithic Revolution on the sediment budgets of drainage systems via new agricultural practices in the Mediterranean Basin, one significant manifestation of this long relationship is recorded in the deposits of numerous ancient Mediterranean harbours. The unique stratigraphic sequence generated in these harbours reflects the superposition of deposits that comprise a clearly identified anthropogenic signature, thus giving rise to a distinct sedimentary suite that differs from the classical coastal infill sequence. Some of these ancient harbours, such as that of Frejus (Forum Julii), in southern France, underwent extremely rapid silting up due to massive sediment sourcing generated by new agricultural practices during the Roman period, and then in the Middle Ages and in the course of the Little Ice Age from the 14th to the 19th centuries, inducing successive downstream relocations of the harbour. The sediment supply from upstream resulted in the rapid growth of deltas such as the well documented cases of the Po and the Ebro.

Human appropriation of the shores of the Mediterranean has resulted in progressive destabilization of the beaches and dunes. Over the 20th century, this situation has been characterized in many ways and in many places by misguided patterns of economic development that have exacerbated coastal erosion while endangering coastal ecosystems. Problems of coastal destabilization and erosion are not simply due to natural causes such as long-term depletion of sediment sources from offshore, or global climate change and sea-level rise. The construction of numerous dams for agricultural and hydro-electric purposes has generated drastic reductions in sediment inputs to deltas and their adjacent beach and dune systems, as shown by examples from the Nile and Rhône rivers. Although direct human intervention on Mediterranean shores not related to harbour development may date back to the tombolos constructed in Tyre and Alexandria by Alexander the Great's engineers during the Hellenistic period, massive engineering interventions with far-reaching consequences are products of port development over the last few decades, either for reasons of international trade as in the case of Tanger, or for leisure and tourism as along the coasts of Spain or of the Languedoc-Roussillon region of France. The multiplication of groynes, breakwaters and sea walls aimed at containing erosion perfectly illustrates the gap between the administrative approach in managing shorelines and ecosystem-based management including coastal sediment cell units. Future sustainable development of the coasts of the Mediterranean can only be achieved via an approach encompassing a wide interdisciplinary spectrum ranging from basic morphodynamic processes through source-to-sink sediment considerations, ecosystem functioning and legislation, among others.