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Surface sediment dynamics along with hydrodynamics along the shores of Tunis Gulf (north-eastern Mediterranean)

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ABSTRACT

The authors report on a study conducted as a part of a project to favour sustainable management of coastal zones, investigating hydrodynamics, sediment dynamics, grain size and mineral composition of surface sediment in Tunis Gulf. Currents, winds and waves affect the erosion, transport and deposition of particles along the coast, leading to an unbalanced sediment budget. Currents recorded in the coastal areas of Port au Prince and Ghar El Melh have an average speed 12 cm s^{-1} during summer but exceeding 20 cm s^{-1} in the case of short strong winds. Numerical simulations of current velocities in the Gulf of Tunis were conducted in both summer and winter. Current velocities reached 20 cm s^{-1} and 10 cm s^{-1} in winter and summer, respectively.

The results of grain-size and mineralogical analyses of surface sediments collected at various depths between Sidi El Mekki and Cap Bon (Tunis Gulf) led to identification of their origin, essentially via transport and deposit. Granulometric study showed that detritus materials in the gulf are of continental origin, while mineralogical analyses revealed a clear relationship between recent sedimentary stock from the gulf and the bordering geological formations. As all sediment distribution is controlled by water movement, a high fraction of fine sediments (>90%) is transported by the major Mediterranean currents and deposited in the gulf's central zone. Coarse sediments, on the other hand, are found at the gulf's entrance in the vicinity of Ghar El Melh Lagoon and, more generally, along the gulf's western shore as a result of littoral transport under wave and swell action.

1. Introduction

A coastline's sediment balance is highly sensitive to any changes that may occur in its environment caused by human or natural interference (Zaaboub et al., 2014). Located in north-eastern Tunisia, Tunis Gulf, whose coastal area has deteriorated due to its sediment budget and shoreline retreat (El Arrim, 1996; Béjaoui et al., 2002; Saidi et al., 2004), is influenced by two important factors. First, a regional current, the Atlantic Water (AT) in the western Mediterranean, enters the Straits of Sicily to split into two branches: one flowing to the south-eastern Mediterranean and the second, called the Atlantic Tunisian Current (ATC), flowing southwards along the Tunisian coast and directly affecting circulation at the mouth of the gulf (Ben Ismail et al., 2012, 2014). The second factor is a large watershed area containing *sabkhas*—an Arabic word designating a coastal and inland saline mud flat built up by the deposition of silt, clay and sand in shallow depressions—along with lagoons, lakes and heavily contaminated rivers on which many dams have been constructed, all of which have caused the coastline to recede further.

Various organic and inorganic contaminants due to both historic and more recent activities (tourism, untreated domestic discharge, agriculture and various chemical and mechanic industries) are injected into the sediments (Afli et al., 2008). In consequence, frequent proliferation of toxic dinoflagellates with associated diarrheic toxins have been detected in clams and mussels in Tunis Gulf (Armi et al., 2011; Aissaoui et al., 2014), yet no sedimentary dynamics along with hydrodynamics along the coast have been reported. The only preliminary management studies reporting sediment instability in Tunis Gulf correspond to a dynamic equilibrium that is constantly changing along the gulf's coastal fringe (Oueslati, 2004; Paskoff, 2004). We therefore hypothesised that currents, winds and waves influence the erosion, transport and deposition of particles along the coast, leading to an imbalanced sedimentary budget. As far as we know, only the southern coastline of Tunisia, especially the Gulf of Gabes, has been studied

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for the driving factors behind sediment dynamics (Brahim et al., 2014).

This report has been compiled as a part of the Tunisian national project ''Dynamics'', and aims to model sediment dynamics and the dispersal of chemical and organic pollutants along the coastal strip of Tunis Gulf. For the first time at this site, the main mechanisms driving sediment dynamics have been studied through a detailed analysis of hydrodynamics, grain size and mineral composition of surface sediments.

2. Materials and methods

2.1. Study site

Located in north-eastern Tunisia, Tunis Gulf (between 37°15 and 36°47, 76′N and 10°53, 60′ and 10°15, 77′E) has a sub-humid and semi-arid climate with a maritime nuance (Fig. 1). The winter period is characterised by strong and frequent north-westerly winds. During the summer, on the other hand, weaker and less frequent winds blow from the east and south-east (Ben Charrada, 1997). Winds from the north-east, though less frequent, generate waves having a great effect on sediment dynamics. The submarine morphology of the western and southern regions is characterised by sandy or sandy-muddy bottoms (El Arrim, 1996; Oueslati, 2004). As stated in the introduction, Tunis Gulf contains a large watershed comprised of lagoons, lakes and sabkhas, as well as numerous streams and rivers, the Medjerda, Meliane, Soltane, Bezirk, Abid and Mghaiez that carry urban input, specially nitrogen and phosphorus.

The geologic origin of the area is Oligo-Miocene, with Pliocene hills and Quaternary plains (Fig. 2). The Oligo-Miocene, with outcrops seen in the Sidi Bou Said and Amilcar hills, consists of a series of clayey sandstones (Ben Ayed et al., 1983), formed by small and relatively consolidated benches separated by brown to black shales. It has a marine facies at the base and a continental one at the top (Jouirou, 1982; Erraoui et al., 1995; M'âamri, 1998). The Pliocene hills present two main facies: lagoon and submarine river-continental (Jouirou, 1982), extending from the shore to Marsa Gammarth beach, and consisting of a series of green clays with rich brownish oysters alternating with lenticular sand banks (M'âamri, 1998). The Quaternary plains cover the entire study area, including both marine and fluvial-continental areas and featuring a Neotyrrhenian conglomerate strombe formation. It is comprised of (1) a rich grey sand layer consisting of reworked shells, red silt with small pebbles and fragments of Roman pottery found in the current dune sands, (2) of alluvium formed by sandy clays and finally (3) of sands and gravels resulting from the floods of the Madjerda and Meliane Rivers (Jouirou, 1982). Tunis Gulf is in a large rift valley formed during the Pleistocene (Azouz, 1973), with a large network of normal faults trending NW–SE to EW and developing small horst and graben (Ben Ayed et al., 1984; M'âamri, 1998).

Following the construction of dams on the Madjerda (dams Mellègue, Sidi Salem, Beni Mandir of Laroussia, Kasseb and Lakhmess) and Méliane Rivers (dams El Kebir and Bir M'cherga) sediment input into Tunis Gulf fell for the two rivers to 4 million and 2.2 million tons, respectively (El Arrim, 1996). This reduction in sediment transported to the beaches was accompanied by the silting of the dams (Table 1); at Sidi Salem dam on the Madjerda, for example, total siltation was estimated at $52 \cdot 10^6\,m^3$ in 1991 (Table 1).

2.2. Sampling

An oceanographic cruise was undertaken aboard the research vessel RV/Hannibal, from 4 to 8 August 2004. A total of 44 surface

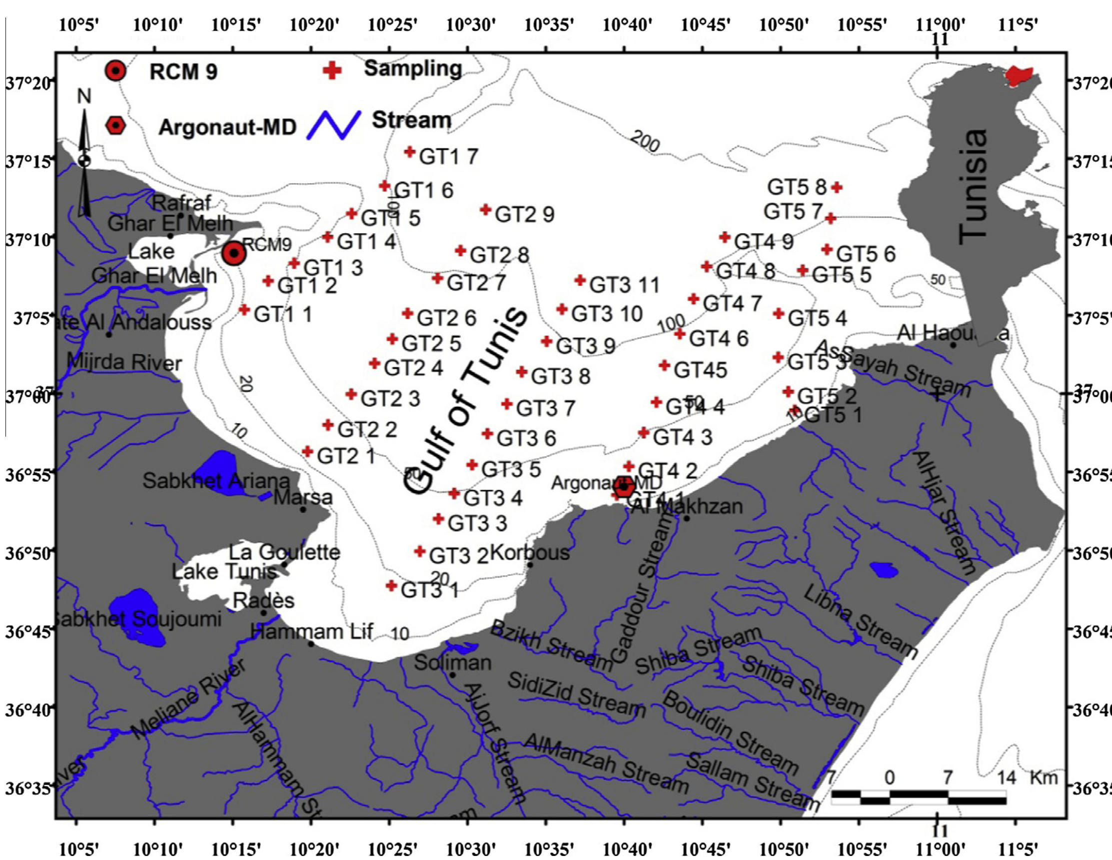

Fig. 1. Study area and sampling sites for surface sediments.