

1 Exploration of the maritime façade of Utica: the potential location of the

2 Phoenician and Roman harbours

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15 Abstract

16 Utica is considered, according to ancient literary tradition, as one of the first three Phoenician
17 foundations of the Western Mediterranean, supposedly founded in 1101 BC by Levantines from
18 Tyre (Tissot, 1888; Carayon, 2008). In the Phoenician and Roman periods, it was an important
19 merchant coastal town, facing the sea. Over the centuries, following the activity of the wadi
20 Medjerda flowing to the south of the city, Utica lost its access to the sea, and its ports became
21 silted up. Despite great interest from archaeologists and associated researchers, the location of

its harbour structures of the Phoenician and Roman periods remains unknown, buried under sediments resulting from the progradation of the Medjerda. Based on the study of sedimentary cores, the research presented here highlights the existence of a long maritime façade to the north of the Utica promontory in Phoenician and Roman times. A deep-water marine environment is attested in the former bay from the 6th mill. BC (Pleuger et al., n.d.) and the height of the water column along the north façade was still 2 m around the 4th – 3rd c. BC. Another [core](#) to the east of the Kalaat El Andalous promontory proved the potential of this sector to have been a sheltered harbour during the Phoenician and Roman periods. Starting from an archaeological problem, this paper illustrates the contribution of geoarchaeology to understand the relations of this ancient city of primary importance with the sea.

1. Introduction and state of the art

Utica (fig. 1) is considered as the largest city of “Libya” (i.e. Africa) after Carthage, according to Appian (*Sic.* II, 3). It is mentioned for the first time in the 4th c. BC in the *Periplus* of Pseudo-Scylax (§111), which also mentions its port (Carayon, 2008). According to the literary tradition, it was founded about 1101 BC by Levantines from Tyre (Pliny, *N.H.* XVI, 216; Pseudo-Aristotle, *Mir. ausc.*, 134). Nevertheless, no archaeological remains date back beyond the 8th c. BC (Monchambert et al., 2013).

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One of the supposed causes of its decline and then its abandonment is thought have been the silting up of its harbour (Tissot, 1888; Bernard, 1911; Paskoff et al., 1991). This would have led the inhabitants of the city to modify their mode of subsistence, previously oriented towards maritime trade, in favour of the exploitation of the surrounding lands (Lézine, 1968). The promontory of Utica, which possessed at least one maritime façade in the Phoenician and Roman periods (Pleuger et al., n.d.), is at present 10 km from the shoreline, following the progradation of the Medjerda delta.

46 Although the port is mentioned in several ancient texts ([cite](#)), its location remains one of the
47 major problems in the study of this archaeological site of primary importance for the study of
48 Phoenician expansion in the Mediterranean. The stratigraphic study of the [port](#) infrastructure
49 would contribute to the understanding of the silting processes responsible for the abandonment
50 of Utica as a port city.

Commented [U2]: Voir Lézine 1966 pour les auteurs anciens sur les ports : Périples de Scylax, Tite-Live, Appien. Stadiasme de la Grande Mer (P ; Arnaud).

51 Since the 19th c., many authors have studied this problem of alluviation, and have proposed
52 various hypotheses for the location of the port. Most of the assumptions [suggest](#)
53 the port [was located](#) on the northern edge of the Utica promontory.

54 Beulé (1861), Daux (1868; 1869), Tissot (1884), and Reyniers (1952) saw in the ruins of what
55 was later interpreted as the Roman Great Baths a monumental war port, in the center of which
56 stood a “Palais Amiral” (fig.2; n°1). To the east of the city, separated from it by a canal, they
57 also supposed a second highly protected trading port (fig.2; n°2). These two ports would have
58 operated during the Phoenician and Roman periods. They would have preceded the foundation
59 of the ports of Carthage and would have served as a model for the latter (Daux, 1868). This
60 hypothesis was subsequently refuted by Cintas (1951), Picard (1953), Lézine (1966), and then
61 definitely excluded by Delile et al. (2015). Indeed, the stratigraphy of a core taken in this area
62 by Delile et al. (2015) prove that the harbour structures cannot be located in the Great Baths
63 sector, since [the bedrock lies above both modern and Roman sea level](#)
64 [here](#).

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65 Reyniers (1951) concluded that the corridor between the promontories of Utica and Kalaat El
66 Andalous was filled early, making Utica a sort of river port at the beginning of the Christian
67 era, accessed from the west between the landings provided by the Medjerda and the wadi
68 Cherchara. This hypothesis is not so far from that proposed later by Delile et al. (2015) and
69 confirmed by Pleuger et al. (n.d.), of a maritime city accessed by an arm of the sea, bypassing

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alluvial bars caused by the progradation of the Medjerda delta. An “anchorage” on the eastern flank of the promontory of Kalaat El Andalous (fig. 2; n°3) was also featured in a drawing by Reyniers evoking the situation in the 1st c. BC.

As Lézine (1966) has pointed out, according to the *Stadiasmus Maris Magni*, of the second half of the 3rd c. AD, there was no port at Utica, only a poor anchorage (*Stad.*, 126). On the other hand, there is mention in the 2nd c. AD of a port (*portus*) capable of receiving large ships at *Castra Cornelia* (*Stad.*, 125) (Ghaddhab, 2016). He also highlighted the fact that in Casar’s descriptions of *Utica* (1st c. BC), only an anchorage is evoked. Merchant vessels were anchored in front of Utica and they left the besieged city without hindrance, so the harbour had to be an open bay and not a closed port (Caesar, *De Bello Civile*, II, 25). Lézine deduced that the pre-Roman built structures were replaced in the 1st c. BC, or before, by a simple anchorage which was gradually suppressed by the sea swell. For him, the silting up of the port(s), and then of the anchorage, was not the result of a change of the course of the Medjerda, but was due solely to the action of the sea. The port of Utica lay to the north-west during the imperial period, because by that time, marshes (mentioned by Caesar) had developed to the south-east of the promontory, confirmed by Pleuger et al. (n.d.).

Another hypothesis was that the corridor between the promontories of Utica and Kalaat El Andalous could have been used as a port-channel, while the area situated to the southwest of Utica could have served as a natural harbour (Carayon, 2008) (fig. 2; n°6–9). However, recent research proves that the wadi Medjerda began to influence the sedimentary accumulation in this corridor from 2600 BC, and that it was entirely silted up during the Roman Empire (Pleuger et al., n.d.).

According to the latest fieldwork, the most likely location of the ancient port facilities would be the north side of the Utica promontory to the east of the Great Baths (fig.2; n°4–5) (Paskoff

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et al., 1991; Paskoff and Troussset, 1992; Chelbi et al., 1995; Slim et al., 2004; Delile et al., 2015b).

This paper presents the results of sedimentary corings carried out on the northern façade of the Utica promontory and to the east of the promontory of Kalaat El Andalous, the preferred areas for the location of the Phoenician and Roman ports. The aim of this research is to propose a reconstruction of the evolution of the coastal environment around Utica and Kalaat El Andalous to identify the potential location of the Phoenician and Roman harbours.

2. Regional and historical setting

Historical and archaeological background

The Medjerda deltaic plain was occupied in the Punic, Roman and then Muslim periods (Chelbi et al., 1995). According to ancient sources (Pliny, *N.H.* XVI, 216; Pseudo-Aristotle, *Mir. ausc.*, 134), Utica was founded three centuries before Carthage in 1101 BC, at the eastern end of the jebel Menzel Roul, in the former *Sinus Uticensis*. Nevertheless, no archaeological remains date earlier than the 8th c. BC (Monchambert et al., 2013). Over the centuries, the city extended to the south (Hay et al., 2010).

In 149 BC, shortly before the third Punic War, Utica became capital of the Roman Province of Africa (Tissot, 1884). This change does not seem to have had an immediate effect on city organisation (Lézine, 1968). During the civil wars, the city was besieged by Curio in 49 BC. It was during this event that Caesar spoke of 200 merchant ships stationed at the port (Caesar, *De Bello Civile*, II, 25). After hearing the news of Caesar's victory at Thapsus (200 km south-east of Carthage), Cato the Younger committed suicide at Utica in 46 BC.

During the reign of Augustus (27 BC–AD 14), the government of the Province was transferred to Carthage but Utica continued to prosper, first as a *municipium*, then as a *colonia* from the

117 reign of Hadrian. The inhabitants seem to have adapted to these changes. During the first two
118 centuries of our era, major urban development projects were initiated (Lézine, 1968), and the
119 city acquired all the public buildings expected in an important and prosperous Roman city,
120 including a port. Most of the city was established within an orthogonal street grid, with a
121 suburban area including pottery and lime kilns as well as cemeteries (ref. reports Wilson, Hay?).
122 The ruins currently cover an area of about 100 ha, suggesting that the population at its peak
123 could have amounted to between 15,000 to 30,000 inhabitants [source?].

124 A notable decline in activity is observed in the late Roman period, although some private houses
125 continued to flourish in the 4th c. AD. The civil basilica was destroyed in the late Roman period,
126 and we have no trace of occupation on the site after the early 5th c., when an earthquake is
127 recorded at the site (Fentress and Wilson, n.d.). The site was reoccupied in the tenth century,
128 when an Islamic village developed on the remains of the city (Kallala et al., 2010; Fentress et
129 al., 2014).

130 About 4 km from the city of Utica was *Castra Cornelia*, a military base established by Scipio
131 during the Second Punic War (218–202 BC) in order to stop the communication between
132 Carthage and Utica (Livy, XXIX, 35, 13–14). It was also used by Curio during the Civil Wars
133 (49 BC). Topographic details given by Caesar during his account of Curio's reconnaissance
134 permits us to place this camp at the site of the present Kalaat El Andalous (Lézine, 1956). He
135 also explains that the way between this promontory and Utica is rendered impracticable by the
136 presence of marshes, and that it is necessary to circumvent the latter by making a detour,
137 approaching Utica from the southwest (Caesar, *De Bello Civile* II.24). Caesar talks about the
138 site as "a straight ridge, projecting into the sea, steep and rough on both sides, but the ascent is
139 more gentle on that part which lies opposite Utica" (Caesar, *De Bello Civile* II.24). The
140 *Stadiasmus Maris Magni* (late 3rd c. AD) speaks of *Castra Cornelia* as a port where ships would

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https://www.academia.edu/12718443/Excavations_at_Utica_by_the_Tunisian-British_Utica_Project_2014

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141 spend the winter conveniently, safe and accessible to the largest ships (*Stad.*, 125) (Chelbi et
142 al., 1995).

143 **Geological and geographical background**

144 The deltaic plain around the promontory of Utica is formed by Quaternary alluvium
145 deposited by the Medjerda, the largest watercourse of Tunisia, and the only
146 perennial river. The reliefs surrounding the plain are traversed by a dense network of wadis,
147 adding to the water supply of the Medjerda in the plain. Anticlinal structures bound the plain
148 on the south (jebels Ahmar and Ennahli) and on the north (jebels Ennadh Hour and Kechabta).
149 These reliefs provide effective natural protection against prevailing winds from the northwest.
150 The plain is divided in two by the anticlinal of the jebel Menzel Roul to the west of Utica and
151 the small horst of Kalaat (i.e., the support of the present city of Kalaat El Andalous). Upper
152 Quaternary clay dunes compose the other hills (Paskoff and Troussset, 1992; Oueslati et al.,
153 2006).

154 The dominant swell comes from the northwest and is deflected by the promontory of Rass
155 Ettarf. It results in a weakened northeast swell, controlling the general orientation of the coast
156 and the meanders of the river for centuries (Pimienta, 1959; Paskoff and Troussset, 1992;
157 Oueslati et al., 2006; Delile et al., 2015a). The tidal range is low, 0.10 m during neap tides and
158 0.30 m during spring tides (Oueslati et al., 2006). Two evolution phases of the Tunisian coast
159 were highlighted by Oueslati (1995) and Paskoff and Oueslati (1988). First, an important
160 progradation of the coast took place during the Punic/Roman period. A study of Anzidei et al.
161 (2011) situates the Roman sea level (1.8 ka \pm 0.05) at 0.58 ± 0.3 m below the local mean sea
162 level (LMSL). The second main phase is characterized by a sea level rise and the advance of
163 the sea. It began after the Roman occupation and continues currently. The Medjerda delta is
164 thus a special case, since the progradation continued after the Roman period and now stretches

for 10 km (Pleuger et al., n.d.; Delile et al., 2015b). The weight of sediments deposited is huge, estimated at 22 million tons per year in the gulf of Tunis (Oueslati et al., 2006). It led to the isolation of Utica from the sea, leaving its harbour infrastructure buried under several meters of alluvium.

3. Material and methods

Coring and radiocarbon dating

This study is based on the mechanical extraction of cores allowing a probe several meters under the alluvium. This technique is a good compromise compared to conventional excavation methods to avoid the problems related to the water table in a delta area (Goiran and Morhange, 2003; Marriner et al., 2010; Goiran et al., 2014). Indeed, the considerable thickness of the sediment accumulation in this area makes it difficult to obtain interpretable geophysical results. The coring points were positioned in x, y, z using a GPS, and a measurement was also taken in the Kalaat El Andalous lagoon to correct the z of each coring according to the current sea level. Two cores were taken: one along the northern façade of the Utica promontory (UTC12) in order to confirm or exclude the hypothesis of the location of the harbour in this sector; the other along the eastern side of the Kalaat El Andalous promontory (KAL1) to see if the environment was suitable for an anchorage during the Punico-Roman period. The AMS radiocarbon datings were calibrated with the OxCal 4.2.4 calibration program (Bronk Ramsey, 2009) using atmospheric IntCal13 or Marine13 curve (Reimer et al., 2013), and reported at the 95% confidence level (2 sigma).

Sampling and analyses

Based on a stratigraphic log, several samples are selected in each stratigraphic unit, and then analysed in the laboratory, using complementary approaches in order to reconstruct the palaeoenvironments and sedimentary processes.

189 Magnetic susceptibility was measured three times by a Bartington MS2E, in order to help to
190 differentiate the stratigraphic units of the core. This signal allows to detect the variations in
191 ferromagnetic mineral contents in the sediment, and it reflects in a deltaic context the detrital
192 flux derived from fluvial processes (Delile et al., 2016). It is expressed in SI (Dearing, 1999).

193 Particle size analysis helps to determine depositional and transport processes. Texture analysis
194 is carried out from a fraction of 30 g of dry sediment. The samples are sieved under water and
195 the sieve residues are weighed to obtain the percentages of the different fractions (coarse
196 fraction (>2 mm), sands (2 mm–63 μ m) and silts/clays (<63 μ m) (Salomon et al., 2014).
197 For particles <2 mm, laser granulometry was performed using a Malvern Mastersizer 2000 (R.U.
198 Inorganic and structural chemistry, Department of chemistry, University of Liège). This
199 technique allows us to obtain the granulometric distribution, the particle size histogram with its
200 cumulative curve, and parameters like the median grain size (D50), which provides
201 hydrodynamic information (Bertrand et al., 2005).

202 Loss-on-ignition (LOI) was performed to estimate the organic and carbonate content of the
203 sediment. After oven-drying at 105°C for 12h, samples are placed in a muffle furnace at 550°C
204 for 4h to determine the organic content, and then at 950°C for 2h to obtain the carbonate content
205 (Heiri et al., 2001).

206 Mineralogical characterisation of the sediment is important in order to understand the genesis
207 of the sediments, deciphering the transport mechanisms, and inferring past limnologic,
208 hydrologic and climatic conditions (Last and Smol, 2002). Bulk mineralogy were carried out
209 by X-ray diffraction (XRD), using a Bruker AXS D8 Advance diffractometer (Cu-K α radiation,
210 40 kV and 25 mA), equipped with a linear detector (LINXEYE XE). Samples of non-oriented
211 powder (Brindley and Brown, 1980) were passed through X-ray diffraction between 2 and 70°
212 2θ with a step size of 0.02° 2θ . Mineral characterisation were determined with the EVA 3.2

213 software and their abundance were calculated in a semi-quantitative way ($\pm 5\%$) following
214 (Cook et al., 1975).

215 4. Results

216 The stratigraphic logs of the two cores UTC12 and KAL1 are described from bottom to top and
217 the depths are expressed in b.s. (below surface). The cores UTC2 and UTC10 (figure 5) are
218 described in Delile et al. (2015b) and in Pleuger et al. (n.d.), respectively.

219 4.1. UTC12 core

220 The core UTC12 was taken in the marshy area north of Utica (fig. 1 and 3). This sector is the
221 most probable location for the harbour, according to the latest studies (Paskoff and Troussel,
222 1992; Delile et al., 2015b). The depth of this core is 9 m b.s. and it can be divided into five
223 major units.

224 The top of unit A (9–6.80 m b.s.) is dated to 373–201 BC at 6.87–6.93 m b.s. This unit is
225 composed of yellow to grey laminated fine sands, between 36 and 91% of the total sample
226 weight. The organic matter rate is between 0.5 and 3%, while the carbonates are between 0.5
227 and 25%. Quartz represents the major part of the mineralogy (40 to 90%).

228 Unit B (6.80–6 m b.s.) is constituted by calcareous crusts interspersed with white clays. The
229 coarse fraction represents up to 65 % of the total sample weight around 6.04 m b.s., but D50 is
230 between 0.004 mm and 0.01 mm. Organic matter composes 2 to 3% of the sediment. The
231 carbonate proportion is high (25–33%), corroborated by the calcite which reach ~65% of the
232 total mineralogical composition. Pyrite is present, but in traces (< 1%).

233 Unit C (6–4.30 m b.s.) is dated from AD 117–252 at 5.51–5.64 m b.s. It is composed of dark
234 marine sands, containing a lot of rolled potsherds. A peak of magnetic susceptibility is observed
235 at 5.14 m b.s. Sands compose the major part of the texture, with 60 to 90% of the total sample

weight. The proportion of organic matter is between 0.7 and 3.5%, and the percentage of carbonates is from 2 to 20%. Dolomite, gypsum and pyrite are present, but all of them reach less than 1% of the total mineralogical composition of the sediment.

Unit D (4.30–3.80 m b.s.) is a peat layer, whose base is dated AD 663–778 (4.14–4.17 m b.s.). Organic matter comprises up to 35 % of the sediment (at 3.91 m b.s.), and the carbonates are between 8 and 15%. Pyrite reaches 5% of the mineralogical composition.

Unit E (3.80–0 m b.s.) is constituted by grey to beige clays, sometimes containing organic matter. Fraction <63 µm composes 90 to 99.5% of the total sample weight, while D50 is between 0.003 and 0.011 mm. Total clays constitute 40 to 50% of the mineralogical composition. The mean of organic matter is 8%, and of carbonates 15%.

4.2. KAL1 core

The core KAL 1 was drilled along the eastern side of the Kalaat El Andalous promontory, in order to check the possibility of an environment suitable for an anchorage during the Phoenician and/or Roman periods (fig. 1 and 4). The depth reached is 11.5 m deep, and the core KAL 1 can be divided into three major units.

Unit A (11.5–6.20 m b.s.) is composed of a very compact layer of dark grey clays with oxide nodules. It can be divided into three subunits. In the first subunit (A1; 11.5–8 m b.s.), fraction <63 µm composes up to 99.6% of the total sample weight. Organic matter represents 10–11% and carbonates 13–14% of the sediment. Subunit A2 (8–6.80 m b.s.) contains a lot of fragmentary shells. The top of this subunit is dated to 1396–1208 BC (at 6.80–6.83 m b.s.). It contains 10 to >30% of elements between 63 µm and 2 mm. The proportions of organic matter are between 7 and 11%, and the carbonates between 13 and 17%. The last subunit (A3; 6.80–6.20 m b.s.) is a layer of laminated grey clays, interspersed with fine sands. Fraction <63 µm

259 represents 98 to 99.5% of the total sample weight. Organic matter is from 10 to 14% and the
260 carbonates from 10 to 15%. Halite and pyrite are present in the whole unit ($\leq 4\%$ and 1%).

261 Unit B (6.20–2.36 m b.s.) is composed of fine ochre sands. The base is dated to 112 BC–AD
262 55 (at 2.80–2.83 m b.s.). This unit can be divided in two subunits. The base of the subunit B1
263 (7–5 m b.s.) is dominated by a silty-clay fraction between 6.86 and 6.19 m b.s. (up to 99.6%
264 of the total sample weight), while the top contains more sands (up to 67%). The organic matter
265 is between 3 and 14% and the carbonates between 10 and 20%. In the subunit B2 (5–2.36 m
266 b.s.) the sandy fraction represents up to 90% of the total sample weight, with coarser sands.
267 Proportions of organic matter and carbonates are lower than in the previous subunit, with
268 respectively 2–4.5% and 12–16%. Quartz represents up to 70% of the mineralogical
269 composition of the sample in the subunit B2. Halite is quite constant in the unit, and decreases
270 very strongly after 3 m b.s. Pyrite is also constant in trace ($\leq 2\%$), but disappears after 4 m b.s.

271 Unit C (2.36–0 m b.s.) is an homogenous layer of ochre clays, corresponding to the present
272 *chott*.

273 5. Interpretation and discussion

274 **The northern facade of the Utica promontory: a potential harbour environment**

275 The base (unit A) of the core UTC12 seems to correspond to a coastal environment influenced
276 by currents (fig. 3). Indeed, the laminated yellow sands that form unit A are between 1.90 and
277 4 m below the ancient sea level. The C/M image (fig. 5; B), which gives indications about the
278 transport and deposit processes, clearly shows that the sediments of unit A were submitted to a
279 graded suspension dynamic, witnessing a turbulent current inducing good sorting. The top of
280 this unit is dated to the 4th–3rd c. BC, which means that during the Punic period, the northern
281 frontage of the Utica promontory was bathed by the sea. Indeed, the height of the water column
282 (between 1.90 and 4 m below Roman sea level) shows that navigation was possible at this time,

283 and that this sector was favourable to the mooring of ships. [The coarse subunit may be the
284 consequence of a storm, or the result of colluvial inputs coming from the slopes of the
285 promontory].

Commented [H10]: L'image CM peut aider à discriminer les deux processus : tempête = relativement bien trié et colluvions = mauvais tri

286 The transition to the next unit, a white carbonate crust, is abrupt. In general, the presence of
287 "calcretes" or carbonate encroachments is taken as an indicator of arid or semi-arid hot climates.
288 Most current or old calcretes are interpreted as having formed in hot climates with an important
289 seasonal moisture deficit (Loisy and Pascal, 1998). Shallow water carbonate sequences in the
290 geological record commonly exhibit numerous exposure surfaces reflecting emersion of
291 sediment due to progradation processes and sea level oscillations (Wright 1994). Moreover, the
292 presence of a calcareous substrate is necessary for the formation of a calcrete, which is not the
293 case here (F. Boulvain, personal communication). [A thin section] revealed the concomitant

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294 presence of quartz grains of very different sizes, blunted or not. This is not common in a
295 calcrete. Many marine fossils and a fragment of volcanic rock are also visible on this thin
296 section. The presence of such a sequence is difficult to explain here. Indeed, taking into account
297 the ancient sea level, the top of this layer of carbonate crust lay under a 1.1 m high water column.
298 Moreover, according the dating of the previous unit (unit A), this layer dates from after the 4th
299 -3rd c. BC and no fluctuation of the sea level of such amplitude can be envisaged at that time.

300 These sediments could thus not have emerged from the sea at any time. It probably represents
301 either natural deposits of evaporation imported from a nearby lagoon or sebkha or an anthropic
302 composite [lime] material composed of crushed shells, sands and maybe fragments of volcanic
303 rock. This lime composition is found in Meninx and Kerkouane at the Punic period (Paskoff et
304 al., 1991). The sharp transition between this layer and the previous unit argues in favour of an
305 anthropogenic deposition. Moreover, this layer is very localised because it is not found in the
306 nearby UTC13 core (fig. 6). During a manual auger survey [within a structure] of the ancient
307 city, a similar carbonate deposit was observed under a Roman soil. It may have been a stabilizer

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Commented [U13]: Demander à Liza

308 used by the Romans (or the Phoenicians?) to consolidate the ground. In the core UTC12, this
309 carbonate unit could be a stabilizing layer deposited for the foundations of a structure, like a
310 mole or another protective structure. A few meters from the coring site UTC12 is a dike erected
311 by a 19th-c. farmer reusing ancient cut stone. This modern structure could eventually been
312 linked to the re-use of elements coming from an ancient mole, built on the same axis.

Commented [U14]: Not likely, as that core was into a Punic ditch.

313 This carbonate deposit is surmounted by a unit C, composed of dark sands mixed with
314 fragmentary shells and ceramic sherds (fig. 3). The sherds are water-worn and their state of
315 preservation prevents any characterization. This unit seems to be linked to a beach deposit,
316 interface between land and sea, a mix of natural and anthropic elements, a reflection of human
317 activities on the coast. The blunted aspect of the sherds and grain size suggests an agitated
318 environment. According the C/M image (fig. 5; B), the unit C presents a dynamic profile and
319 was set up by rolling combined with graded suspension. With the decrease of the water column
320 due to the sedimentary accumulation, the influence of the swell increases from unit A to unit C
321 and induces a higher turbulence. If a mole or any protective structure was present, it must lie to
322 the west of this point, which was exposed to a significant hydrodynamism, the dominant swell
323 coming from the northeast. Taking into account the age-model (fig. 5; A), the basis of the unit
324 would date from the 1st c. AD (a mean of AD 35 at 6 m b.s.). But it should be noted that the
325 previous unit can constitute a time gap in the age-model, if it is an intentional deposit very
326 limited in time. At this point the height of the water column in Roman times was 1.1 m, which
327 is too low even for the navigation or anchorage of a small boat (Boetto, 2010). This sector was
328 thus used as a mooring site during the Roman era, rather than as a port. According to the age
329 model and the ancient sea level, the aggradation of the sands follow the rise of the sea level
330 until the 7th c.

Commented [a15]: I think this is a bit speculative. The evidence is not sufficient to start proposing a harbour mole here.

Commented [U16]: Brune aussi car elle reçoit les égouts et fonctionnement du port ? Il faudrait des analyses de paléo-pollution
→ Hugo. Activités biologiques qui appauvrissent le milieu en oxygène (Pimienta 1953). Dépôts d'évaporation d'une lagune ou sebkha à proximité ? Pour la datation, vérifier sachet 687-693 : est-ce bien la bonne unité ?

331 The core UCN2 (fig. 1 and 6), drilled 600 m north of UTC12, showed that there was a marine
332 environment about fifteen meters deep in the Punic and Roman periods (Pleuger et al., n.d.).

333 The bay situated to the north of Utica was thus able to shelter a large number of boats anchored
334 in it, while smaller boats could be drawn up onto the beach or dock on a mole or other port
335 structure. It is essential to locate the shoreline and assess the height of the water column to
336 determine the maximum draft of ships that could access the port. The draft of a fully loaded
337 vessel restricts its access to port infrastructures. Its dimensions also limit its circulation
338 capacities (Boetto, 2010). Utica's northern bay, with a large span and wide opening, allowed
339 any type of boat to manoeuvre. The deep bay of Utica, open towards the east, constituted indeed
340 a natural harbour protected from the prevailing winds coming from the northwest.

341 Given the stratigraphy of the UTC10 core and associated dates (fig. 6), it is also probable that
342 a port area was active in Roman times here. Much of the stratigraphic sequence of UTC10 could
343 be interpreted as fluvial inputs generated by the progradation of the mouth of the Medjerda
344 River. The chronological gap (0.33 cm/yr of sedimentation rate) between the two deepest
345 datings of UTC10 can be interpreted as an artifact generated by a dredging action, as underlined
346 in similar cases (Salomon et al., 2017). It appears that around 1 BC–AD 130, a water column
347 of 4 m was still available at the UTC10 coring point. From the 4th c. AD, a rapid sedimentary
348 accumulation is observed (from 0.33 cm/yr between 8.60 and 7.40 m b.s. to 7.3 cm/yr between
349 7.40 m b.s. and 5 m b.s.). The first sedimentation rate is too low to be natural, especially near a
350 threatening stream. This can only be explained by an anthropic control of sedimentary
351 accumulation, i.e. dredging. It was only later in the 4th c. that the sedimentation rate exploded,
352 which can be explained by a major alluvial crisis in the Medjerda river and by the cessation of
353 dredging by the inhabitants of Utica, because of an excess of sedimentation of the river. The
354 abandonment of dredging is probably also related to the notable decrease in the city activity in
355 the late Roman period (Fentress et al., 2014).

356 In the core UTC12, the development of a peat bog is then attested after the 7th or 8th c. AD,
357 slightly above the current sea level. This dating from the base of the peat level is older by two

centuries compared to the peat sequence of the UTC2 core described in Delile et al.(2015b) and of UTC10 (fig. 6), suggesting that the peatland developed from east to west over the centuries, at a rate of 1.2 m per year. It can also be deduced that at the end of Antiquity, the embarkation area was more localized in the western part. Moreover, the absence of any peat layer in UTC13 suggests a localized peatbog (fig. 6). Even localized, the presence of marshes would have made the place less and less comfortable and inauspicious for occupation.

Thereafter, a radical change in the environment is observed in the stratigraphy since the vertical accretion of the bog stops and leaves room for clays probably of fluvial type, evidence for the gradual influence of the floods of the wadi Medjerda.

The northern frontage of the promontory of Utica became gradually unusable from the 4th c. AD, and was definitely isolated from the sea from the 7th c. AD, following fluvial contributions (Pleuger et al., n.d.; Delile et al., 2015b). Then a peatbog progressively developed, stretching from east to west until the 10th c. AD. A final environmental change occurred when the development of the peatbog stopped to leave room for alluvial deposits.

East facade of the Kalaat El Andalous promontory: a potential harbour shelter

The base of the KAL1 coring (unit A; fig. 4) consists of compact dark grey clays with exceptional induration. The particularly dark colour of this unit is due to the reducing environment, the presence of organic matter that has not been oxidized. The presence of oxidized pyrite nodules attests also a reducing and calm environment. The clay deposit testifies to a calm subtidal environment. The A2 subunit would be the result of a storm or a landslide (presence of marine shells, spines of sea urchins, pebbles, etc.) at least for the top of the subunit. Bioturbation occurred later and resulted in the mixing and transport of these elements deeper in the subunit. The top of this A2 subunit dated from 1396–1208 BC, which supports the idea that this storm occurred before the legendary foundation of Utica and may have partly altered

382 the configuration of the east facade of the promontory. In the A3 subunit, the numerous
383 subhorizontal sand-clay laminations organized into multiple laminasets, [indicative of high-
384 frequency waves, also favour a storm origin like that described in Morton et al. (2007)].

Commented [H17]: Si on regarde le paramètre de la texture, cette subunit A3 pourrait correspondre au « mud cap » que l'on retrouve dans les dépôts de tsunami.

385 The following unit is composed of fine ochre sands, witnesses of a less calm marine
386 environment than in the previous unit. The upper part of this unit is dated from 112 BC–AD
387 55 at 2.80–2.83 m b.s. According to the age model (fig. 5; C) and the Roman sea level, a water
388 column of 2.85 m height was available at the time of the legendary foundation of Utica, or 1.80
389 m if taking account of the oldest archaeological remains (8th c. BC) (Monchambert et al., 2013).
390 In the Phoenician period, then, there was thus a coastal environment suitable for mooring
391 vessels, to access to the promontory from the less steep side to the southeast on a gentler slope
392 and sheltered from the prevailing winds coming from the northwest. An environment of higher
393 energy is then attested with the sub-unit B2, which corresponds to the Roman sea level
394 according Anzidei et al. (2011). This sub-unit is marked by coarser sands and with the
395 disappearance of pyrite.

396 Taking into account the age model and the Roman sea level, sands emerged from the 3rd c. BC.
397 In Roman times, the mooring of ships was thus no longer possible at this point, but only further
398 east of the promontory to reach the shore or further south, where the slopes are still more gentle.
399 Indeed, at that time, the northwest tip of the promontory was already inaccessible because of
400 the silting of the corridor between the two promontories of Utica and Kalaate Al Andalous
401 (Pleuger et al., n.d.).

402 Fluvial influence begins to be felt from unit C, whose base is +1.24 m above the Roman sea
403 level, when the muds from the mouth of the wadi flowing from the tip of the promontory began
404 to seal the area and create a swamp/sebkha environment. Indeed, the C/M image (fig. 5; D)
405 shows that unit C presents a very different profile from that of the previous unit, marine and

better sorted (Salomon, 2013). This unit C corresponds to decantation mixed with graded suspension, showing that the environment became influenced by the floods of wadi Medjerda. According to the age model, this influence began around the 3rd–4th c. AD (AD 208–368 at the base of Unit C). This date agrees with the advancement of the delta to the north of the promontory of Kalaate highlighted in (Pleuger et al., n.d.).

The eastern façade of the promontory of Kalaat El Andalous presented an environment suitable for a mooring of ships in Phoenician times, but the shoreline had already receded in Roman times, and the mooring of ships therefore took place in a more distal position to the east of the promontory (fig. 7).

6. Conclusion

The deep north bay of Utica offered interesting port potential in the Phoenician period which evolved over the centuries with the progradation of the Medjerda delta (fig. 7). Anchorage was possible in the bay, and the mooring of boats could be envisaged on the north face of the Utica promontory, in agreement with Delile et al. (2015b), but also on the northwest and the eastern face of the promontory of Kalaat El Andalous. During the Roman period the anchorage in the northern bay of Utica (more than 15 m of water column) and mooring along the northern frontage of the promontory of Utica remained conceivable until the 4th c. AD, when the fluvial threat became too important and dredging was abandoned. Afterwards, a peat bog started to develop along this facade, following its isolation due to the alluvial deposits carried by the wadi.

This chronology is in agreement with archaeological research, which underlines a slowdown in the evolution of the city from the 4th c. AD. The Utica harbour system was perhaps a simple anchorage, as evoked in the *Stadiasmus Maris Magni*, but it is probable that a mole or another protective structure was part of the port structures after the 4th–3rd c. BC, which could be supported by the carbonate deposit in the core UTC12. A systematic geophysical survey on the

430 northern façade area of the Utica promontory, as well as an archaeological survey at the UTC12
431 coring point, might confirm or refute this hypothesis. Mooring was probably still
432 possible along the east side of the Kalaat El Andalous promontory, but more to the east than to
433 the Phoenician period. It is probable that this promontory was no longer an island at the time of
434 the first Phoenician settlement, because the corridor between it and Utica was
435 already filling at that time. Nevertheless, systematic coring to the southwest of this promontory
436 could attest if it was an island before the foundation of the city.

437 7. Acknowledgments

438 Frédéric Boulvain

439 Tournesol; ERC; Envimed

440 8. References

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Figure 1: Location map of the coring points

**Figure 2: Schematic map of Utica with the different hypotheses of the location of port structures
 according to the different authors. The numbers are referred into the text.**

587 Figure 3: Stratigraphic log of the UTC12 core

588 Figure 4: Stratigraphic log of the KAL1 core

589 Figure 5: Age model (A) and C/M diagram (B) for UTC12; age model (A) and C/M diagram
590 (B) for KAL1. D: decantation; US: uniform suspension; GS: graded suspension; R: rolling. C/M
591 representation of Unit D in UTC12 is not applicable because it is a peat accumulation.

592 Figure 6: Cross-section figure of the corings carried out in the northern façade of the Utica
593 promontory

594 Figure 7: Schematic map of Utica and its port potentialities around the 8th c. BC and around the
595 2nd c. BC.

596 Tab. : Radiocarbon datings