



## Méditerranée

Revue géographique des pays méditerranéens / Journal of Mediterranean geography

104 | 2005

Environnements littoraux méditerranéens, héritages et mobilité

---

# Harbours and Holocene variations of the shoreline between Andriake and Alanya (Turkey)

*Les variations holocènes des littoraux entre Andriaque et Alanya (Turquie)*

Éric Fouache, Patricia Sibella and Rémi Dalongeville

---



### Electronic version

URL: <http://mediterranee.revues.org/2322>  
DOI: 10.4000/mediterranee.2322  
ISSN: 1760-8538

### Publisher

Presses Universitaires de Provence

### Printed version

Date of publication: 1 avril 2005  
Number of pages: 87-94  
ISSN: 0025-8296

### Electronic reference

Éric Fouache, Patricia Sibella and Rémi Dalongeville, « Harbours and Holocene variations of the shoreline between Andriake and Alanya (Turkey) », *Méditerranée* [Online], 104 | 2005, Online since 30 January 2009, connection on 30 September 2016. URL : <http://mediterranee.revues.org/2322> ; DOI : 10.4000/mediterranee.2322

---

The text is a facsimile of the print edition.

Tous droits réservés

## Harbours and Holocene variations of the shoreline between Andriake and Alanya (Turkey)

*Les variations holocènes des littoraux entre Andriaque et Alanya  
(Turquie)*

Eric FOUACHE\*

Patricia SIBELLA\*\*

Rémi DALONGEVILLE\*\*\*

**Abstract** - Evidence of Holocene shorelines from Kemer to the border of Syria has been previously shown (EROL, 1963; KELLETAT, 1975; DALONGEVILLE and SANLAVILLE, 1977, 1979). In the context of the programme entitled «Evolution of coastal landscapes in the Eastern Mediterranean along the last six millennia», Rémi DALONGEVILLE gave us the opportunity (FOUACHE et al., 1999; FOUACHE, 2001), to revisit this question on the section of coastline between Andriake and Alanya. The objective was to resume an inventory of coastal formations and systematically prioritize three types of markers, the geomorphological markers (notch, beachrock, bench), the vermetid bioconstructions, and the archaeological markers (partially submerged quarries, harbour structures), in order to reconstruct the variations of the Holocene shore. Harbours, both ancient and medieval, are numerous throughout this section of the coast and incompletely studied (BLACKMAN, 1973a and b, 1982a and b). The authors' study is also an opportunity to try and understand the possible consequences of the relative sea level on the functioning of the better-known harbours.

**Résumé** - La mise en évidence de lignes de rivages holocènes fossiles au sud de la Turquie, de Kemer à la frontière syrienne, est ancienne (EROL, 1963 ; KELLETAT 1975 ; DALONGEVILLE et SANLAVILLE, 1977, 1979). Dans le cadre du programme de recherches intitulé «Évolution des lignes de rivage en Méditerranée Orientale au cours des derniers 6000 ans» et dirigé par Rémi DALONGEVILLE, nous avons eu la possibilité de compléter ces observations (FOUACHE et al., 1999 ; FOUACHE, 2001). Dans nos prospections nous avons privilégié trois types de marqueurs susceptibles de nous aider à positionner les lignes de rivage holocènes fossiles : les marqueurs géomorphologiques (encoche, beachrock, trottoir), les constructions organogènes de vermetes et les marqueurs archéologiques (carrière partiellement ennoyée, structures portuaires). Les vestiges de ports antiques et médiévaux sont nombreux sur tout le secteur de côté étudié, mais encore incomplètement inventoriés (BLACKMAN, 1973a et b, 1982a et b).

The region under study (Fig. 1) begins at the island of Kekova, which is situated five kilometers to the southwest of Andriake and was affected by a significant subsidence after an earthquake in the second half of the 2<sup>nd</sup> century AD (FOUACHE et al., 1999), and concludes at Alanya. This rocky promontory is the site of the ancient city of *Coacesium*, which was a haven for pirates until its destruction by Pompey in 67 BC. The city reached its apex in the 13<sup>th</sup> and 14<sup>th</sup> centuries under the Seljuk sultanate, when it was the principal maritime arsenal and controlled

shipping in the Gulf of Antalya. From Kemer to Alanya, and on to the border of Syria, one can identify markers of the shoreline that indicate a relative submergence, but the markers of uplift are particularly dominant (DALONGEVILLE et al., 1993; EROL and PIRAZZOLI 1992; KELLETAT and KAYAN, 1983). In addition to geomorphological observations, the archaeological sites of Andriake, Olympos, Phaselis, Side, Okurçalar and Alanya have also attracted our attention. From the point of view of seismic activity over the past half century, this

\* EA 435, UMR 8591, CNRS, Universités de Paris I et Paris XII, 94010 Créteil Cedex. eric.G.fouache@wanadoo.fr

\*\* Institute of Nautical Archaeology, Texas, USA

\*\*\* UMR 5133, Laboratoire Archéorient, environnements et sociétés de l'Orient ancien, Maison de l'Orient Méditerranéen, Université Lumière Lyon 2, 7 rue Raulin, 69 007 Lyon.

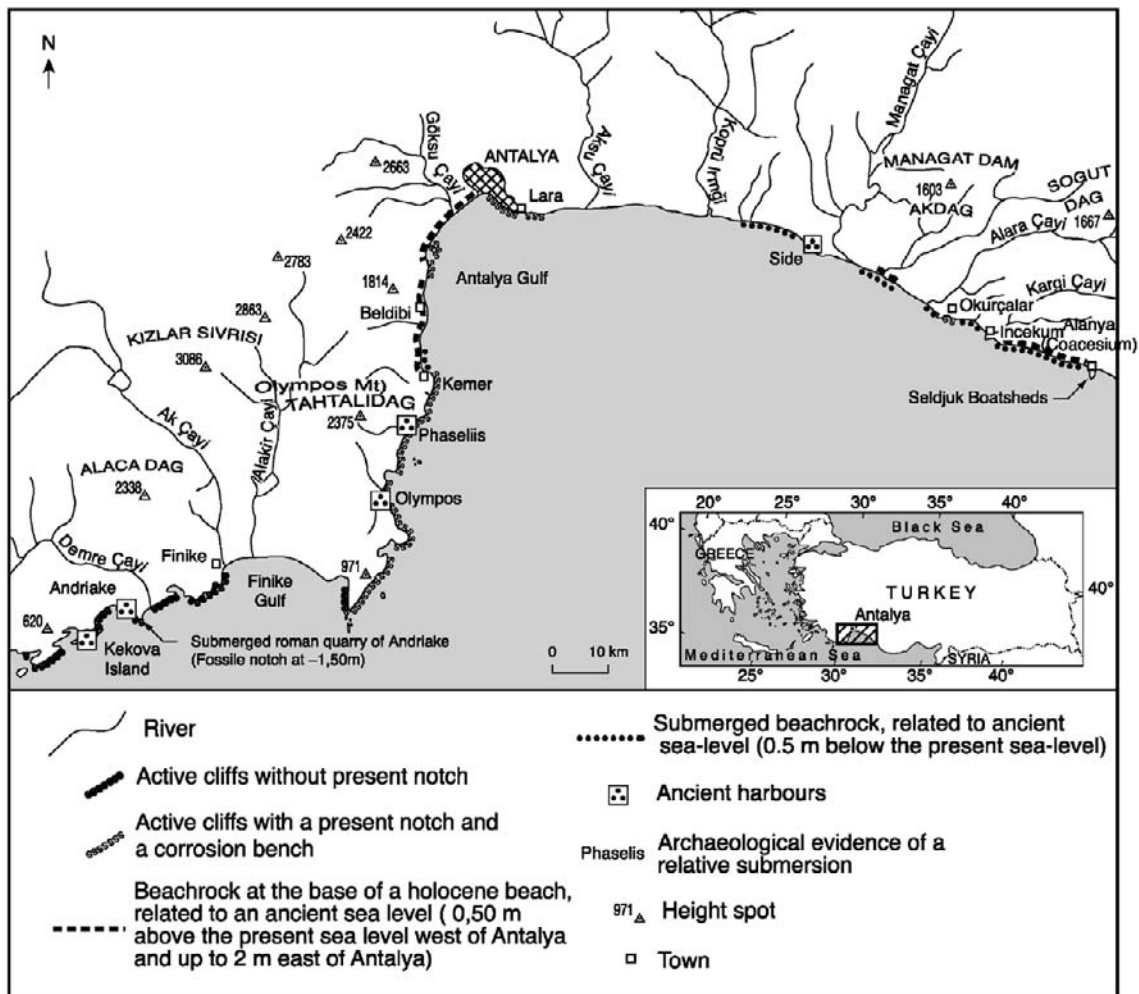


FIG. 1 - HOLOCENE FOSSILE SEA-LEVEL INDICATORS BETWEEN ANDRIAKE AND ALANYA

region is also interesting for being located on either side of the Finike peninsula, which is the border of two well-differentiated tectonic zones (Fig. 1). To the west of the peninsula, in the zone situated on an extension directly in front of the Aegean arc, earthquakes greater than magnitude 5.0 on the Richter scale are frequent (GLOVER *et al.*, 1998). To the east, in contrast, they are few. One may wonder whether this geological boundary matches up with the distribution of geomorphological markers of ancient shorelines, and whether any tectonic conclusions may then be inferred.

## 1. Methodology

Our objective was to resume an inventory of coastal Holocene sea level indicators between Andriake and Alanya in order to establish a relative chronology of sea level changes. We identified three types of fossil sea level indicators, the geomorphological markers (notch, beachrock, bench), the vermetid bioconstructions and the archaeological markers. For the latter, taking into account the methodology developed by FLEMMING (1979-80) and PIRAZZOLI (1979-80) we have selected in BLACKMAN (1973 a and b) the submerged archaeological remains that

were undoubtedly related to an ancient sea level, that is, harbour structures, partially submerged quarries. All these indicators do not have the same precision as regards the sea level. The most precise and reliable of all are the vermetid bioconstructions, often linked to benches. Then as far as geomorphological markers are concerned, notches are due to the action of the corrosion by the sea at the midlittoral level. The retreat point of a notch corresponds to the average sea level (PIRAZZOLI, 1986), which makes it a rather precise indicator. However, the precision decreases with the intensity of the action of the waves on the cliff. As for beachrock, the cementation occurs inside an active beach or under a superficial presence of *cyanobacteria* (BERNIER & DALONGEVILLE, 1988; NEUMEIER, 1998) in the intertidal zone and needs a prograding system. Considering the progradation, we have assumed that the average sea level corresponded to the middle of the fossil beachrock slab. Thus, in a context of low tide, such as in the south of Turkey, we have estimated the imprecision to  $\pm 20$  cm. As for the archaeological indicators, in our case they are the most approximative indicators, but they prove extremely useful when combined with the other indicators, as they provide information about either a minimum or a maximum level.

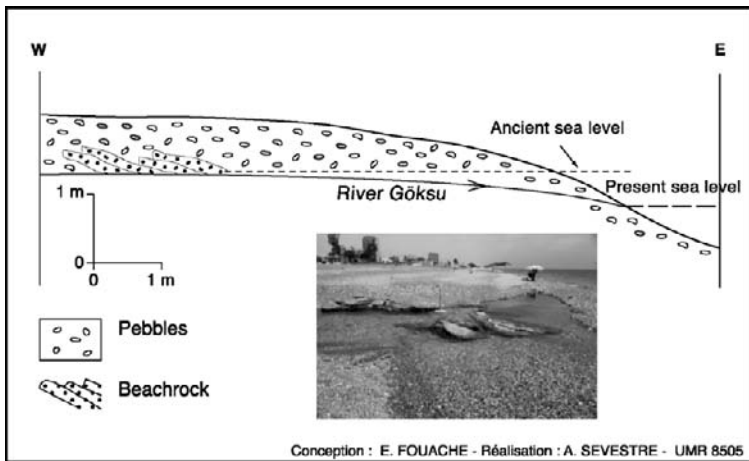


FIG. 2 - BEACHROCK AT THE MOUTH OF RIVER GÖKSU

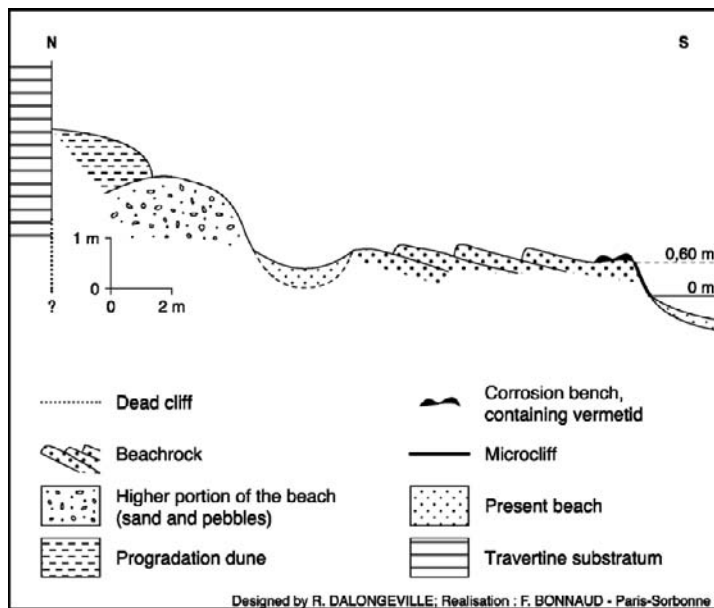


FIG. 3 - FOSSIL HOLOCENE BEACH AND BEACHROCK AT THE FOOT OF THE TRAVERTINE CLIFF EAST OF ANTALYA

## 2. Two fossil Holocene shorelines between Kemer and Alanya

Immediately to the west of Antalya, in the rear of that gulf, and in the bays of Beldibi and Kemer, large shores have developed in front of dune formations. To the east of Antalya, once past the developing delta of the Aksu stream, the beaches become sandy but are always located ahead of dune formations. One encounters a few rocky sections up to Alanya, the limestone promontory of Side, the sandstone cliffs of Okurçalar (which are of local slabs of sandstone detached from the rock in a place that mimics perfectly a false beachrock), the conglomerate limestone promontory of Incekum and the one emerging in Alanya. This entire section of the coast, to the west and east of Antalya, presents abundant evidence for fossil shorelines (Fig.1).

### 2.1. From Kemer to Alanya, evidence of a submerged shoreline at -0.5 m

In the bay of Kemer, one can clearly observe an

assemblage of beachrock slabs, in the process of breaking up, visible up to five meters from the present shoreline and down to one meter under water. The highest slab, part of which is out of the water but the majority is submerged, includes in a carbonated matrix of nearby pebbles of the same type as the pebbles that constitute the storm cordon of the actual beach. We therefore believe that this slab represents the highest level of the fossil beach, the mediolittoral level of which is found about 0.5 m below the present level. One submerged slab, with the same characteristics as that of Kemer, has been observed as well, thanks to an incision caused by an inlet channel between a costal pond and the sea and established inside a cordon of pebbles at the mouth of the river Göksu (Fig. 2). But it is to the east of Antalya, however, in the vast sandy beaches that dominate that zone and which all recognize today to be an ongoing erosion, where one observes the largest beachrocks (Fig. 1). The submerged slabs are visible along the entire coast, up to several meters from the shore, and down to one meter deep. They appear there also to correspond approximately to a marine level of around 0.5 m below the present level. But both west and east of Antalya, there are also some beachrock that suggest a relative marine level situated above the present level (Fig. 3).

### 2.2. Some traces of a relative sea level superior to the Modern one between Kemer and Alanya

At Kemer, there are pieces of beachrock slabs, 40–50 cm long and 10–15 cm thick and imbedded in a fossil beach of consolidated pebbles which are located under a dune about twenty meters behind the Modern beach. Locally these fragments can be interpreted perhaps as the remains of the submerged slab, displaced by virtue of a storm, but other evidence, more and more obvious as one moves eastward, testifies to a stabilisation phase of a relative sea level around 0.5 m above the modern level.

On Beldibi beach, even more numerous pieces of slabs of the same general shape are visible, while to the north of that shore, the foot of the cliff carries the spectacular mark of a large fossil notch partially packed with pebbles, with a highpoint situated 0.5 m above the present level. Such a highpoint is not always absolute evidence of an ancient sea level but as we move towards the east of Antalya there are more and more incontestable remains of a relative sea level situated above the present-day level. In effect, the loose formations that occupy the rear of the bays are surrounded by sections of living cliff, which have also preserved, here and there, traces of a relative sea level higher than that of the present.

At the base of the cliff of Antalya, cut into the thick travertine, a one-meter wide notch with a bench has

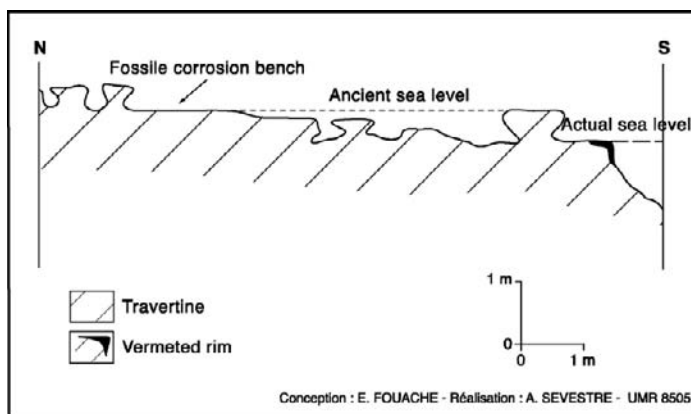


FIG. 4 - FOSSILE CORROSION BENCH AT LARA RELATED TO AN ANCIENT SEA-LEVEL LOCATED 0.5 M ABOVE THE PRESENT ONE

developed, as well as a small vermeted rim. In the travertine cliffs to the east of the bay of Lara, one also observes a bench and a notch corresponding to the contemporary sea level, and the broken remainder of a fossil bench situated 0.5 m above the present level (Fig. 4). It is at Incekum, inside the Miocene calcium conglomerates in the west of the site, that this fossil bench is the best preserved. It reaches approximately four to five meters in width.

Sections of beach as well carry traces of sea levels higher than those of the present. On leaving Perakende and all the way up to Alanya, in addition to the submerged slabs of beachrock, there are other beachrocks visible on the beach itself up to two meters above the present sea level. Such is the case particularly to the south of Alanya and between Side and Okurçalar. In contrast to what one sees west of Antalya, these beachrocks are more than one meter higher than the present shoreline, and it is likely that they are just a continuation of the slab formations that are now one meter under water.

The archaeological remains are relatively abundant along this section of coast, beginning with Greek colonization and progressing onwards. They provide us with dating markers which allow us to propose a chronology of variations in the shoreline, at over the past 2500 years.

### 3. Using archaeological remains as chronological indicators of fossil shorelines

From Kemer to Alanya, all sections of cliff, formed of carbonated rock, which may be composed of travertine, of conglomerate limestone or limestone rocks show a basic notch cut into the cliff face with a more or less developed bench on the border of which one observes the formation of a vermeted rim.

#### 3.1 The present mean sea level has been reached since at least the Seldjuk Sultanate time

The extent of these forms of corrosion/bio-

construction implies that the present sea level was reached no later than the 13th century AD. The more imposing harbour remains that exist in this area consist of the boatsheds of the Seldjuk arsenal of Alanya (Fig. 1). These sheds are situated to the east of the promontory of Alanya, at the foot of the cliff. They were built in 1227 during the reign of Sultan Kaykubat I Ala ad-Din and are associated with the fortification of the Seldjuk marine arsenal. Five boat ramps were erected and covered with fine vaults of stone. Each has a length of 43 meters and a width of 7.5 meters. They open directly onto the sea and so provided shelter for five galleys ready to be put to sea with great rapidity. These ramps were used until the beginning of the 20th century and the entire complex is in an excellent state of preservation. Diving at the foot of these ramps

allowed us to determine that the foundations were made of large limestone blocks resting directly atop the bedrock, which was carefully cut to accommodate them. The first levels are also constructed of stone, up to above the present sea level. Then, alternating courses of brick and stone are used. The entire structure is still functional and even with the present sea level. All of the archaeological remains we observed along the coast that predate the Seldjuk period bear testimony to a general relative subsidence. The most spectacular evidence is situated to the west of Kemer, near the site of Andriake.

#### 3.2 A fossil Roman notch at -1.5 meters below present sea level in the ancient quarry of Andriake

Once one reaches the peninsula of Finike, the sections of limestone cliff are no longer marked with a basic notch at the present mean sea level.

The site of Andriake (FOUACHE *et al.*, 1999) (Fig. 1), which is situated near the modern village of Demre, occupies a bay into which the Androkos River flows. The site was occupied from the Hellenistic to the Byzantine periods and was one of the principal ports on the circuitous wheat route that linked Egypt to Rome. The existence of this port is mentioned in texts from the early 2<sup>nd</sup> century BC on. In 197 BC, Antiochus III anchored there in the course of his expedition to retake control of the Anatolian coast for the Ptolemies. The remains of the port area consist of quays and associated warehouses, most of which are now silted in by the river. The main quarry of the site is located to the west of the port at the tip of a limestone promontory. Access to the quarry was achieved either on foot over the promontory or by sea. The visible traces of tools on the face of the rocks, both circular marks and V-shaped marks, are characteristic of tools used during the Roman period (BESSAC, 1988), which corresponds to the apex of the period of building at the site.

The working floor of the quarry is now under water, the importance of the submersion varies according to the different levels of exploitation, indicating submergence since the Roman period. On diving below

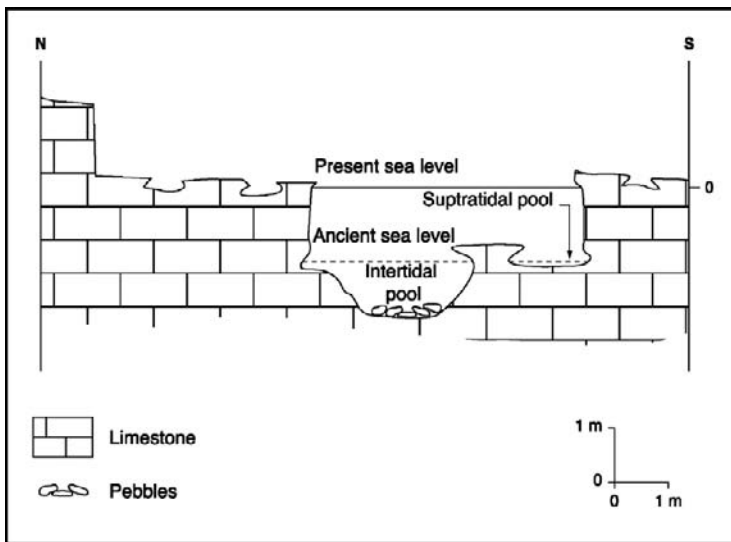


FIG. 5 - SUBMERGED ANCIENT QUARRY OF ANDRIAKE

one of these floors, we have been able to identify a fossil notch, situated at 1.5 meters below the present sea level (Fig. 5). Associated above that notch, but still submerged, bowls and basins were observed, something that has already been described about another submerged quarry in Tunisia (DALONGEVILLE in PASKOFF *et al.*, 1981), that is to say a formation that is characteristic of the wider coastal zone. The depth below surface of the notch is consistent with the time constraints for the use of the quarry and corresponds, in our opinion, to a phase of stabilisation in sea level during the Roman period. Was the extent of submersion equivalent to that of the two other ancient ports of Olympos and Phaselis, that are situated to the west of the Finike peninsula?

#### 4. Archaeological information on the relative variations of sea level at Phaselis, Olympos, Side and the acropolis at Okurçalar

##### 4.1. Phaselis

Phaselis (FOUACHE *et al.*, 1999) was founded in 690 BC by colonists from Rhodes. The city appears to have been abandoned after its conquest by the Seldjuks in 1158, since there is no further mention of it in written sources. The acropolis is located on top a living cliff, where one observes the development of a bench and a notch comparable to that of Antalya. Phaselis was built on a narrow peninsula that allowed for the development of three ports. The south port was sheltered from strong, southeasterly winds and waves by a breakwater, constituted of large, accumulated blocks on an extension of dry land (BLACKMAN, 1973b, 358-362), which has been largely dismantled on the upper part of its structure, and which now lies at a depth of about five or six meters. According to BLACKMAN, Scylax makes a reference to the

breakwater, which therefore would date back to no later than the 4<sup>th</sup> century BC. The central port, which is constructed on the other side of the peninsula, at the foot of the acropolis, is entirely enclosed by a jetty. The quay is still visible, as well as some reused moorings now set horizontally. The port's entry channel is no more than 18 meters wide, which restricted access to small- and medium-sized boats. This port seems to have come into use beginning in the 1<sup>st</sup> and 2<sup>nd</sup> centuries AD (BEAN, 1968). The north port is an anchorage in an open bay situated to the northeast of the peninsula and protected by a natural sandbar that was reinforced with stone in order to form a breakwater. The upper part of this breakwater remains visible today under meter of water. On the northern edge of this bay, the remains of an aqueduct that supplied the town with water still stand, only now with its support pillars in the

water, which provides a supplementary indicator for submergence during the Byzantine period. While taking account of the different pieces of evidence, this submergence does not appear to have been more than one meter.

##### 4.2. Olympos

The first mentions in ancient texts of the city of Olympos come from the writings of Plutarch and Scylax in the 2<sup>nd</sup> century BC. The city was then a member of the Lycian League, which was composed of 213 cities. The city was completely abandoned in the 15<sup>th</sup> century. The port, which was one of the most important on the southwest coast of Turkey, was harboured in a rocky inlet at the mouth of a mountain stream. Visible remains today (FOUACHE *et al.*, 1999) include a quay bordering the left bank of the stream and equipped with a warehouse. The quay, of which the principal structure dates from the Hellenistic period, displays some repairs and reshaping of blocks from the Roman and Byzantine periods. Vessels from all of these periods were able to sail up the rocky inlet about a hundred meters until they reached a bridge, whose central support pier can still be identified in place in the middle of the channel. Today, the rocky inlet has been largely silted in behind a bar of pebbles. The shore enclosed, moreover, a portion of the medieval constructions, which shows that the alluvial deposition is relatively recent. This geomorphological transformation had already occurred in the 11<sup>th</sup> and 12<sup>th</sup> centuries when first the Venetians and then the Genoese fortified the port directly on the bay of Daliktas, which is situated at the opening of the rocky inlet. It is noteworthy that a notch that is even with the Modern sea level is visible at the foot of the limestone cliffs that surround the bay. The port of Olympos thus did not supply us with direct evidence for Medieval coastal submersion, but it did for the formation during a relatively short span of time, between the 4<sup>th</sup> and 12<sup>th</sup> centuries, of an imposing pebble bar, which caused the silting in of the ancient port.

To the east of Antalya the archaeological markers

are fewer, and concentrated around Side and the acropolis of Okurçalar.

#### 4.3. Side

This city was founded in the 7<sup>th</sup> century BC by Greek colonists from Kyme (STRABO XIV, 6, 67), which was situated near present-day Izmir. Side occupies a promontory between Antalya and Alanya (Fig. 1). It reached its commercial zenith along with the other coastal cities in the region during the 2<sup>nd</sup> century AD at the height of the Roman Empire (MANSEL, 1963). At the start of the 3<sup>rd</sup> century AD Side began to decline before regaining some importance in the 5<sup>th</sup> and 6<sup>th</sup> centuries. The Arab raids of the 7<sup>th</sup> through the 10<sup>th</sup> centuries ruined it, and the inhabitants sought refuge in Antalya. In 1895 the site was re-occupied by Turkish refugees from Crete. The visible archaeological remains at Side are numerous, but we refer to those only in relation to the marine level. Fortification foundations of the 4<sup>th</sup> century AD are located today either exposed to the sea northwest of the site, or submerged southeast of the promontory below the temple of Apollo. To accommodate the foundation stones, the bedrock, a limestone conglomerate, had been hollowed out in accordance with a shape particularly well-suited to a self-supporting structure (KNOBLAUCH, 1977). Relative submersion since the early Byzantine period has been at least forty centimeters from those foundation features and without doubt a little more.

#### 4.4. The acropolis at Okurçalar

The acropolis at Okurçalar contains numerous, visible Byzantine remains. To the west of the acropolis, and at the rear of the bay, is located the popular vacation beach of Cimtu. Nowadays, at the eastern end of the beach, the rocky promontory that constitutes the acropolis of Okurçalar is a living cliff. This has not always been the case, as evidenced by a large slab of beachrock that is bound to the cliff at the present medio-littoral level and submerged one meter deep. This beachrock is ancient testimony to a beach that once covered the foot of the cliff and corresponded once again to the relative sea level around 0.5 meters below the present. From the body of the slab, we retrieved a large unidentified sherd, indicating the slab presence for at least the historical period. Tests for <sup>14</sup>C (Ly-13001), carried out by the laboratory of the Center of Radiocarbon Dating of Lyons on a sample of the carbonated matrix of this slab gave a date of 3505 ± 90 BP. Since we could not date the cement, but the whole matrix, it is possible that this dating may be distorted by the presence of carbonates stemming from re-cementation and aging.

Our survey between Andriake and Alanya identified evidence of two shorelines between Kemer and Alanya, situated both above and below the present shoreline. For the beach sections, there are two fossil beachrocks corresponding to two different shorelines, one situated around -0.5 m, the other at +0.5 - in relation to the present sea level. In the areas of cliff, we have identified a notch with a bench and a small vermeted rim, a fossil bench, and a fossil notch at Beldibi which also correspond

to a relative sea level around +0.5 meter in relation to that of the present. It is only on the site of the partially submerged quarry of Andriake, where there is no notch or actual bench, that we were able to observe a fossil notch, contemporary with the period of the quarry's use and corresponding to a relative sea level situated at -1.5 meters in relation to that of the present.

## 5. Discussion

The fact that a higher Holocene shoreline (+0.5 meter) is located below imposing ancient dune formations and is essentially preserved by beachrock slabs indicates that it is linked to a phase of massive sedimentary accumulation and progradation of the beaches. That this level left few visible notches and fossil benches at the foot of the cliff implies that the majority of the cliff base was thus masked by the beach formations. Since no shoreline archaeological remains have been identified in relation to the level situated at +0.5 meter, we may deduce that this higher shoreline was created some time between the height of the Flandrian Transgression (around 5500 BP) and the start of Greek colonisation (ca. 600 BC).

#### 5.1. Dating of the shoreline situated at -0.5 meters from Kemer to Alanya

The ancient shoreline on this stretch of coast ca. 0.5 meter below the present sea level roughly coincides at numerous points with the submersion of archaeological remains at Olympos, Phaselis, Side and Okurçalar. It would be tempting to assign the existence of this shoreline to a rather long period, perhaps more than a millennium, which would span from at least the 4<sup>th</sup> century BC to the 4<sup>th</sup> or 5<sup>th</sup> centuries AD. One site only, located west of the Finike peninsula, the Roman quarry of Andriake, provides us with a relative submergence of 1.50 m. Yet the period of use of that quarry falls well within the bracketed chronology that we have established. The submerged notch found at Andriake is contemporary to the shoreline established between Kemer and Alanya at -0.5 m. Its submergence of more than one meter and the absence of an intermediate notch in the quarry encourage us to correlate the two levels. While a nonsymmetrical eustatic reconstruction was impossible, it follows that the establishment of the shoreline at its present level is due to tectonic subsidence.

#### 5.2. The tectonic origins of the present shoreline

Indeed, many steep cliffs, formed by north-south faults and Quaternary in origin, have been identified in the region, with a high concentration to the southwest of Antalya (GLOVER and ROBERTSON, 1998). Beginning at the Finike peninsula, one enters into a zone of recurrent

violent seismic activity, as is indicated on a chart of earthquakes of magnitude five and over that occurred between 1964 and 1997. The tectonic origins of the present sea level being established, it would be tempting to place this period of uplift in the «Early Byzantine tectonic paroxysm (EBTP)», (PIRAZZOLI *et al.*, 1996) between the 4<sup>th</sup> and the middle of the 6<sup>th</sup> centuries AD. The section of the coast between Antalya and Andriake is located in a geological hinge position between the coastal section of Antalya to the Syrian border to the east, where traces of higher Holocene sea levels dominate, and Kekova to the west, where Late Byzantine/Seldjuk-period subsidence seems to surpass the  $-1.50$  m measured at Andriake. This shift could have been rapid, or even coseismic, from Kemer to Alanya, but it is certain that the sea had stabilised at its present level by the end of the 13<sup>th</sup> century. Subsidence in the vicinity of  $0.5$  m accounts for the submersion of archaeological structures such as those observed at Phaselis and Side. In contrast, the Finike peninsula continued to subside, which would explain why no corrosion features developed on the cliffs to the extent observed east of the peninsula, from Olympos to Alanya. The recent geomorphological evolution of the site of Olympos is equally clear. The port of Olympos was built downriver on a small, torrential river that empties into a rocky inlet at the extreme south of the bay of Daliktas.

Today the inlet is blocked by a bar of pebbles, while some medieval structures are partially sanded in at the top of the beach by an advancing shore. The rise of the sea level here allowed longshore drift to carry in large quantities of pebbles, which migrated progressively south until they obstructed the entrance to the port, reducing drainage from the inlet and causing silt brought downstream from the mountains to build up. This situation already existed in the 11<sup>th</sup>-12<sup>th</sup> centuries when the Venetians and the Genoese successively fortified the port directly inside the bay instead of further into the inlet itself. Thus it is now possible to compare the absolute chronology for the evolution, during the height of the Flandrian Transgression, of the shoreline of southern Turkey to that section of shoreline reconstructed farther to the east on the Syrian coast, at the site of Guverdjine Kaya in Syria (DALONGEVILLE *et al.*, 1993; SANLAVILLE *et al.*, 1997). This site is used for comparison since it possesses a relative chronology of ancient beach development that is well bracketed by <sup>14</sup>C datings.

### 5.3. Comparison with the site of Guverdjine Kaya in Syria

The cliffs of Guverdjine Kaya are developing at the expense of Helvetian limestone and vertical rock. Here beachrock is visible, although it is more or less hidden

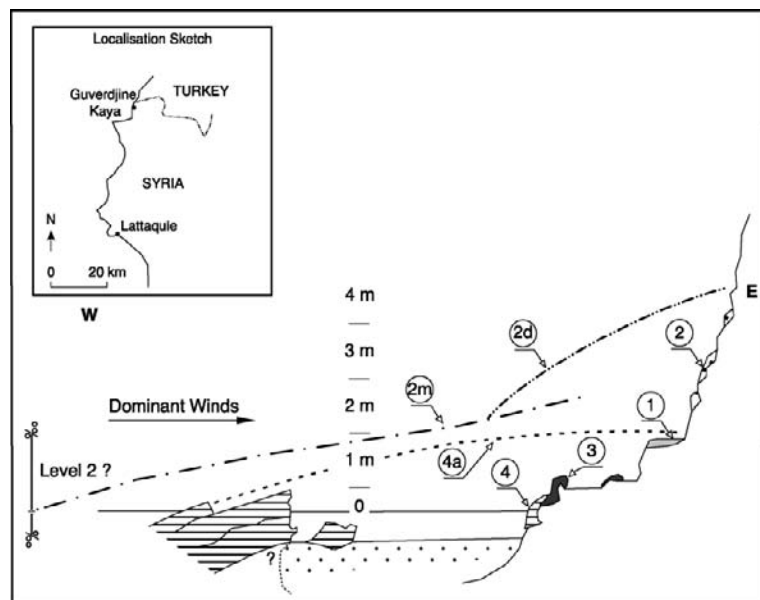


FIG. 6 - HOLOCENE FOSSILE SEA-LEVEL INDICATORS AT GUVERDJINE KAYA (Adapted from DALONGEVILLE *et al.*, 1993 )

- 4: Old cemented beach, now a beachrock; 4a : Profile of the beach, linked to the beachrock;
- 3: Biostrom containing Vermets (1890  $\pm$ 55 BP), linked to a corroded surface, +0,60 m level;
- 2: Coating of beach sediments cemented on the surface of the cliff (dated 3590  $\pm$ 70 BP to 2945  $\pm$ 55 BP) corresponding to an undefined marine level (+1,20 m ?); 2d: Profile of the dune, associated to the coating of beach sediments; 2m : Profile of the beach, associated to the coating of beach sediments;
- 1: Biostrom containing Vermets

beneath the present beach. The top of the beach rises to five meters above the line of very strong tides where it is then followed by a sand dune. The dune itself is ten meters above high tide, and was created by the force of the prevailing westerly winds. There is limestone that has preserved the essential features of Holocene hydrodynamics, which consist of forms of corrosion (notches, benches, hollows of the basin type), and of fossilised organic deposits (shell layers) or else superficial deposits of shell sediment. The following facts are highlighted (DALONGEVILLE *et al.*, 1993; SANLAVILLE *et al.*, 1995; SANLAVILLE *et al.*, 1997), in a dynamic sequence that constructs a relative chronology before allowing for an absolute chronology based on four <sup>14</sup>C results (Fig. 6). The quotes on height are given according to the average present sea level:

**Stage I:** the creation of the first bench of corrosion (+1.20 m), accompanied by superficial deposits of shell (*Dendropoma petraeum*) dated to 5595  $\pm$  85 BP. The sea is therefore in contact with the living rock of the cliff.

**Stage II:** substantial sedimentation thickens the foot of the cliffs to the point of developing a wide beach at the foot of the cliffs which are now becoming dead cliffs. It is probable here, as is the case further south in the Arab al-Malek sector, that the beach sediments survived in a beachrock, but that they were eventually eroded completely.

**Stage III:** the sea was once again in contact with the cliff (+0.60 m) where it cut another bench of corrosion, which is more visible in a bay situated immediately to the north



of the area of primary observation. The accretion of shell ceased, an event dated to  $1890 \pm 55$  BP (AD 416-650).

**Stage IV:** new sedimentation covers the traces of previous coastal episodes accumulated in the limestone. Although less active and substantial than the previous sedimentary event, a beach is formed which cements into the form of beachrock. A large part of this rock is still preserved today but it has not been possible to date it.

**Stage V:** return of the sea into contact with the cliff, to the modern sea level.

The fossil sea level indicators that we have identified in southern Turkey correspond quite well with Stage II for the large superficial sediment deposits, with Stage III for the construction of benches of corrosion and the development of beachrock where beaches continued to advance, and with Stage VI for the establishment of the Modern shoreline. We hope that the campaign of  $^{14}\text{C}$  dating that we expect to undertake in the course of 2004/2005 will enable us to clarify our hypotheses.

## Conclusion

Southern Turkey occupies, from the point of view of recent regional seismic activity, a hinge position between the termination of the Aegean arc and the coasts of the Levant. This hinge seems to be situated at the apex of the Finike peninsula and to have played a role, beyond

recent activity, in the distribution of tectonic displacements during the entire Plio-Quaternary period and beyond. It would be interesting to compare our observations of Holocene shoreline displacements with a similar terrestrial survey, with an eye to identifying evidence of recent playbacks along the length of the fault. Yet, to the east of the Finike peninsula, seismic activity has been dormant since the 13<sup>th</sup> century.

The period of the «Early Byzantine tectonic paroxysm (EBTP)», between the 4<sup>th</sup> and the middle of the 6<sup>th</sup> centuries AD, as described by PIRAZZOLI, seems to correspond well to the last stage of intense seismic activity that modified the shoreline on a vast regional scale and brought about a subsidence of 0.5 m. The presence of beachrock indicates that long phases of stability have also marked the evolution of the shore. Nevertheless, if there are features of the Holocene shoreline visible today above the present marine level, they can only be a result of tectonic movements, which the study attributes to a general uplift over the last 6000 years. Apart from the importance of the tectonic factor in the displacement of the shoreline, the true originality of southern Turkey resides in the presence of two ancient shorelines, one below the present sea level and one above, on the very long stretch of coast from Antalya to the Syrian frontier. The MALRHO program (*Marqueurs des Lignes de Rivages Holocènes/Holocène Sea Level Indicators*), financed by the *Commission des Fouilles du Ministère des Affaires Étrangères* and directed by Rémi DALONGEVILLE and Eric FOUACHE, aims at establishing a radiometric

chronology in order to verify the hypotheses of our relative reconstitution of sea level variations in the area.

## REFERENCES

- BEAN G.E., (1968), *Turkey's Southern Shore*, London, Benn.
- BESSAC J.-C., (1988), Problems of identification and interpretation of tool marks and ancient marbles and decorative stones, in HERZ, N., and WAELKENS, M., (eds), *Classical Marble: Geochemistry, Technology and Trade*. NATO ASI ser. E 153.
- BLACKMAN D.J., (1973a), Evidence of sea-level change in ancient harbours and coastal installations, *Colston papers*, vol. 32, p.115-139.
- BLACKMAN D.J., (1973b), The harbours of Phaselis, *IJNA*, vol. 2, n° 2, p.355-364.
- BLACKMAN D.J., (1982a), Ancient harbours in the Mediterranean, part 1, *IJNA*, vol 11, n° 2, p.79-104.
- BLACKMAN D.J., (1982b), Ancient harbours in the Mediterranean, part 2, *IJNA*, vol 11, n° 3, p.185-211.
- DALONGEVILLE R., et SANLAVILLE P., (1977), Témoins de lignes de rivage holocènes en Turquie méridionale, *Bulletin de l'Association Française d'Étude du Quaternaire*, n° 4, p.79-81.
- DALONGEVILLE R., et SANLAVILLE P., (1979), Rivages holocènes de Turquie méridionale, *Bull. Lab. Rhod. Géomorph.*, Bron, n° 4-5, p.5-15.
- DALONGEVILLE R., LABOREL J., PIRAZZOLI P., SANLAVILLE P., ARNOLD M., BERNIER P., EVIN J., MONTAGGIONI L.-F., (1993), Les variations récentes de la ligne de rivage sur le littoral syrien, *Quaternaire*, n° 4, p.45-53.
- EROL O., (1963), Die Geomorphologie des Orontes Deltas und der anschließenden pleistozänen Strand- und Flussterrassen (Provinz Hatay, Türkei), *Ankara Üniversitesi Fiziki Gografya Docenti*, 148, p.65-110.
- EROL O., and PIRAZZOLI P., (1992), Seleucia Pieria: an ancient harbour submitted to two successive uplifts, *IJNA*, vol. 21, n° 2, p.317-327.
- FOUACHE E., SIBELLA P., DALONGEVILLE R., (1999), Holocene variations of the shoreline between Antalya and Andriake (Turkey), *IJNA*, vol. 28, n° 4, p. 305-318.
- FOUACHE, E., (2001), *Dynamiques holocènes et évolutions de lignes de rivage de l'Adriatique au sud de la Turquie*, Vol III HDR «Approches géoarchéologiques en domaine balkanique et méditerranéen», Université de Paris IV, 274 p
- GLOVER C.P., and ROBERTSON A.H., (1998), Role of regional extension and uplift in the Plio-Pleistocene evolution of the Aksu Basin, SW Turkey, *Geol. Soc.*, n° 155, p.365-387.
- KELLETAT D., (1975), Eine eustatische kurve das jüngere holozän, konstruiert nach Zeugnissen früherer Meeresspiegelstände im östlichen Mittelmeergebiet, *N. Jb. Geol. Paläont.*, n° 6, p.360-374.
- KELLETAT D., and KAYAN I., (1983), Alanya batisindaki kiyılarda ilk  $^{14}\text{C}$  tarihlendirmelerinin ışığında Geç Holosen tektonik hareketleri, *Türk. Jeol. Kurumu Bül.*, vol C, n° 26, p.83-87.
- KNOBLAUCH P., (1977), Die Hafentlagen und die anschließenden Seemauern von Side. Ankara: *Türk tarih kurumu basimevi*, 58 p.
- MANSEL A.M., (1963), *Die Ruinen von Side*, Deutsche Archaeologische Institut, Abteilung (Istanbul) (ed.), Berlin, W. de Gruyter and Co, 208p.
- PASKOFF R., TROUSSET P., DALONGEVILLE R. (1981), Variations relatives du niveau de la mer en Tunisie, depuis l'Antiquité, *Histoire et Archéologie, les dossiers*, n° 50, p.52-59.
- PIRAZZOLI P., LABOREL J., STIROS S., (1996), Earthquake clustering in the Eastern Mediterranean during historical times, *J. Geophysical Research*, vol 101, B3, p.6083-6097.
- SANLAVILLE P., DALONGEVILLE R., EVIN J., (1995), Rythmes et modalités de l'évolution du littoral syrien à l'holocène, in *Les milieux littoraux*, Actes du colloque AGF, Lille 17 mai 1905, *BAGF*, n° 5, p.410-427.
- SANLAVILLE P., DALONGEVILLE R., BERNIER P., EVIN J., (1997), The Syrian coast: a model of Holocene coastal evolution, *J. Coastal*