Morphological and sedimentological characteristics of a cuspate foreland (Mytikas Epanomi, east Thessaloniki city, Greece)

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ABSTRACT

Cuspate foreland is a geographical feature developed in a long shore drift or lakeshores. It is formed in a downwind area of an island or a coast, or at the end of a river where the conditions are appropriate by the incremental progress of sand and gravels in a triangle shape. The formation of the shape depends on the wave refraction and the deposition of sediments at the two sides of the triangle.

Some cuspate forelands are flushed with floras which emigrated from the main land and they consist of many geomorphological features, like the lagoon and different types of dunes. Such kinds of ecosystems are sensitive to the human's activity and nature.

The subject of this research was the geological history and geomorphological characteristics of such a cuspate foreland. To this purpose, electric resistivity tomography (ERT) method was employed to map the vertical sequence of sediments in such an environment.

The research was focused on a specific cuspate foreland at 'Mytikas' in Epanomi, close to Thessaloniki. The main purpose of the work was to map the surface sediments as well as the stratigraphy in depth and to record all the features that are developed on it and which contributed to the forming of this ecosystem.

Mytikas is a wealthy ecosystem, with triangular shape, demarcated by two streams. It has a variety of dunes, which extend on both sides of the triangle. In the inland, there is a chocked lagoon with a diameter of 5.5 km (Kjerfve,1986), which hosts many kinds of birds. Accretion zones are found on the South side of the cuspate foreland and the main direction of the wind on this side is towards the North.

Based on the sedimentology and pipette analysis of the sediments collected from the surface and the lagoons, the area is composed of grit sandy mud.

Another part of the research was focused on mapping the surface features. In this specific figure, were extracted the results for the shape of the secondary dunes, which gave information for compiling an elevation model of the dunes.

Nine ERT profiles in total were measured in the study area. The images that have been produced by the ERT data inversion, allow the estimation of the age of the cuspate foreland, as well as the age of the lagoon. Another ERT was applied to correlate the resistant layers with the stratigraphy of the area in general.

KEYWORDS

Cuspate Foreland, Geomorphology, Dunes, Lagoon, ERT (Electric Resistivity Tomography), Sedimentology.

INTRODUCTION

Epanomi is located 28Km SE of Thessaloniki and the village is 4km from the east cost of the Thermaikos Gulf, in the exit of a flat valley. Epanomi covers a territorial scope of 78,849 stremma, of which 5,000 stremmas are the survey area of Mitikas or known by locals as “Fanari”. The coastline of this area 35km. The settlement of Epanomi is crossed by a torrent with orientation from North East to South West, that ends in the sea.

The cuspate foreland begins from the North terrestrial part of the cultivation area and it ends in the South part of Thessaloniki’s prefecture, close to the borders of Chalkidiki's prefecture. It is on the opposite side of the marsh Kitros Pierias. More specifically, the lagoon is located in the South West part of Epanomi as a marsh which expands for $1km^2$. The shape of this geomorphologic form is isosceles triangle with $5km^2$ area. Even though the lagoon covers a small area, it has a wide variety of flora, fauna, dunes and sandy coasts.

The cuspate foreland fauna consists of amphibians, reptiles and mammals, some of which are protected species. The main characteristic of the area is the species richness of birds. More than 210 different species are counted in this area.

Because of the importance of the flora and the fauna in this area, this lagoon was included in the European Union of Natura 2000.

GEOLOGICAL CHARACTERISTICS

From a geological point of view the study area is under Axios Zone and more specifically under Paionia's Subzone. The entire East area has only Neogenic sediments in horizontal layers that consist of alternations of clay – silt, sandy Clay – sandy silt, sandy marl, sand and thick layers or lens of sandstone. The sediments thickness is about 200m and the deposition occurred during the Pliocene (Gonias Formation).

Coastal terraces are the morphological feature of the area. On their base there is a sandy coast, which provides protection from the waves to the vertical forehead of the terrace, depending on its length. Where the coast has a small length, erosion is faster and the terrace retreats. The material of the erosion is mostly sand, which is deposited to the lower part of the coast, due to coastal transfer (Chronis 1986, Albanakis et al., 1999).

Gonia Formation

It’s above Trilofos formation and underneath Moudania formation. The main amount of the sediments is located in the west part of Katsika mountain, east of Rema stream and north of Kallikratia – Flogita coast. It appears in smaller scale to the North West part of Kassandra peninsula, south east of Thessaloniki and in the area of Megalo Embolo – Plagiari.

A sedimentological variety appears in this formation, in parallel or crossed layers of sand – sandstone, clay, conglomerate, marl, limestone in layers – lenses. The thickness of these sediments is 100m – 150m.

Moudania Formation

Moudania formation is a more recent formation that covers Gonias formation. The two formations are separated by surface erosion (Siridis, 1990).

The sediments that appear gradually to the East part of Gonias formation, cover the whole landscape of the lowest relief, south of Holomontas mountain and on the north part of Kassandra peninsula. Similar sediments appear to Megalo Embolo in Michaniona. Its thickness can reach 200m.

This formation includes a big amount of terra rossa, which consists of lenses of pebbles, sand – sandstone with cross-layers of sandy clay – silt. Despite of the granulometri of the materials, all layers and lenses include brown red fine grained material that gives a unique colour to the sediments.

FIELD WORK

Field work was carried out during five months in summer 2011.

Three different sections took place. Firstly, sedimentary samples were collected from the surface. Then, the dunes were mapped with a GMS-2 Topcon GPS receiver and during the last section, an electrical tomography was used to generate an image of the near surface stratigraphy.

Furthermore, samples were collected from the rupture wave zone, from the dune zone and from the environment of the lagoon. The distance between two consecutive coastal samples was fixed -one kilometer- and each time on a vertical line form the coast. Two other samples were taken from the dunes and the lagoon environment. A GPS point completes the sediment collection.

In order to delineate the deposit environment, satellite images were used. Then a separation took place for the subenvironment deposits. The samples were taken from a depth of 10cm to 15cm. These samples were after all elaborated in the laboratory with two methodologies, Pipette and Sieving, which will be further analyzed henceforth.

The second part included the mapping of all the geomorphological features of the area, the coast line, the lagoon environment, the dunes and the accretion zone, mapped with the GMS-2. With the dunes mapping the creation of an elevation map was made possible.

For the last part of the research, eleven electrical tomographies were applied in different places of the cuspate foreland, in order to monitor the near surface stratigraphy of the area. Four tomographies of 1km took place around the area, two of 250m, one in the entrance of the lagoon, one at the end of the lagoon and five tomographies of 120m in the flooded lagoon environment.

LABPRATORY METHODOLOGY

The collected samples have been weighed and prepared for the chosen method. Initially, they were cleaned from roots and small pieces of wood and then the weight of each sieved sample was written down on a table separately. The percentage of each sample was calculated and the procedure continued with the addition of these two.

If the sample has a coarse grain size (gravels, sand) then the sieve method is used, otherwise, the Pipette method is preferred, because in that case the sample consists of clay, silt, and very fine sand. In many cases both methods are used, because the samples are mixed with many different materials. In this case, it is recommended to start with the sieving method and procede until the shieving powder is more than 5% of the total sample. Then, for the remaining fine sediment the procedure continues with the method of Pipette.

For the specific study area both methods were used. For the sieving method, the diameter of the sieves was from -2Φ to 4Φ, included the shieves of -1.5Φ, -0.5Φ, etc., for the coarse grain size of the coastal zone. For the samples of the lagoon environment, where the material is very fine sand, the Pipette method was preferred.

The important of these two methods is the cumulative percent by weight of the granules per sample. This percent will need to calculate the size of parameters (Folk, 1974, Ψιλοβίκος, 1985). This parameters are the average (x)(The best graphic measure for determining overall size is the Graphic Mean, given by the formula $x = \frac{\Phi 16 + \Phi 50 + \Phi 84}{3}$,it corresponds very closely to the mean as computed by the method of moments, yet is much easier to find. It is much superior to the medium because it is based on three point and gives a better overall picture. This will be the standard measure of size used. Folk,1980) standard deviation ($s = \frac{\Phi 84 - \Phi 16}{4} + \frac{\Phi 85 - \Phi 5}{6.6}$) (It is very close to the standard deviation of the statistician but is obtained by reading two values on the cumulative curve instead of by lengthy computation (Folk, 1980)), the skewness ($Sk = \frac{\Phi 16 + \Phi 84 - 2 \times \Phi 5}{2(\Phi 84 - \Phi 16)} \times \frac{\Phi 5 + \Phi 95 - 2\Phi 50}{2(\Phi 95 - \Phi 56)}$), and curvature ($Ku = \frac{\Phi 95 - \Phi 5}{2.44(\Phi 75 - \Phi 25)}$) and they load in Gradistat software to give triangle diagram’s to understand sedimentarys of the study area (Tab.1, 2).

Table 1: Sedimentological analysis of the coast samples and the dunes samples.

COAST

SAMPLES	Description of sediment distribution	x	σ	Sk	K
1Π	Two peaks	1.1257 moderately sand	1.0295 poorly sorted	- 0,404 strongle coarse skewed	1.439 leptokurtic
2Π	One peak	1.3835 moderately sand	0.8577 moderately sorted	-0.3081 strongle coarse skewed	1.2043 leptokurtic
3Π	Two peaks	0.7174 coarse sand	1.2227 poorly sorted	-0.2513 coarse skewed	0.7597 platykurtic
4Π	Three peaks	0.0760 coarse sand	1.0907 poorly sorted	0.2199 fine skewed	1.0642 mesokurtic
5Π	Two peaks	-0.3964 very coarse sand	0.7854 moderately sorted	-0.0716 near symmetrical	1.1544 leptokurtic
6Π	Two peaks	-0.8921 very coarse sand	0.7788 moderately sorted	0.04233 near symmetrical	0.6944 platykurtic
7Π	Three peaks	-0.3334 very coarse sand	1.1774 poorly sorted	0.0761 near symmetrical	0.6511 πολύ platykurtic
8Π	Three peaks	0.5433 coarse sand	1.1784 poorly sorted	-0.3738 strongle coarse skewed	0.8541 platykurtic
9Π	Two peaks	-0.3291 very coarse sand	1.5190 poorly sorted	0.5097 strongle coarse skewed	0.5662 πολύ platykurtic

DUNES

SAMPLES	Description of sediment distributio	x	σ	Sk	K
1Θ	One peak	1.4794 moderately sand	0.4964 well sorted	0.0493 near symmetrical	1.0280 mesokurtic
2Θ	One peak	1.7350 moderately sand	0.5522 moderately well sorted	0.0177 near symmetrical	0.9672 mesokurtic
3Θ	One peak	1.273 moderately sand	0.5893 moderately well sorted	0.0418 near symmetrical	0.9522 mesokurtic

Table 2: Sedimentological analysis of the accretion zone samples and the lagoon environment.

ACCRETION ZONE					
SAMPLES	**Description o sediment distribution**	**x**	**σ**	**Sk**	**K**
16 ZE	Two peaks	2.3360 sand	0.9534 moderately sorted	-0.1976 coarse skewed	0.6928 platykurtic
17 ZE	One peak	1.9123 moderately sand	0.8559 moderately sorted	0.07284 near symmetrical	0.9871 mesokurtic
18 ZE	One peak	-0.0225 very coarse sand	0.5484 moderately well sorted	-0.0389 near symmetrical	1.0797 mesokurtic
19 ZE	One peak	-0.0347 very coarse sand	0.7874 moderately sorted	0.0741 near symmetrical	1.4539 leptokurtic
20 ZE	Two peaks	1.0012 moderately sand	0.7609 moderately sorted	0.2895 καλή λοξότητα	0.8347 platykurtic
21 ZE	One peak	0.1020 coarse sand	0.6851 moderately well sorted	0.0145 near symmetrical	1.0188 mesokurtic
LAGOON					
SAMPLES	**Description o sediment distribution**	**x**	**σ**	**Sk**	**K**
1Λ	Two peaks	1.5185 moderately sand	0.9889 moderately sorted	0.0234 near symmetrical	1.4491 leptokurtic
2Λ	One peak	1.7630 moderately sand	1.1110 poorly sorted	0.7260 very well sorted	2.6371 πολύ leptokurtic
3Λ	Two peaks	1.8637 moderately sand	0.7039 moderately sorted	0.1448 well sorted	0.8848 platykurtic
10Λ	Two peaks	0.8445 coarse sand	1.1568 poorly sorted	0.2333 well sorted	1.4062 leptokurtic
11Λ	Two peaks	2.0011 sand	0.7176 moderately sorted	0.1027 well sorted	0.7478 platykurtic

STUDY AREA BOUNDARIES

For a better understanding of the study area, a bigger area was digitized with the ArcGIS software, while a gdem was extracted from the entire gdem map of Greece. Furthermore, by applying the command "Hydrology" of the ArcToolbox, the drainage pattern was created (fig.1). From the drainage pattern the conclusion was drawn that the study area is surrounded by two torrents that are seasonally active.

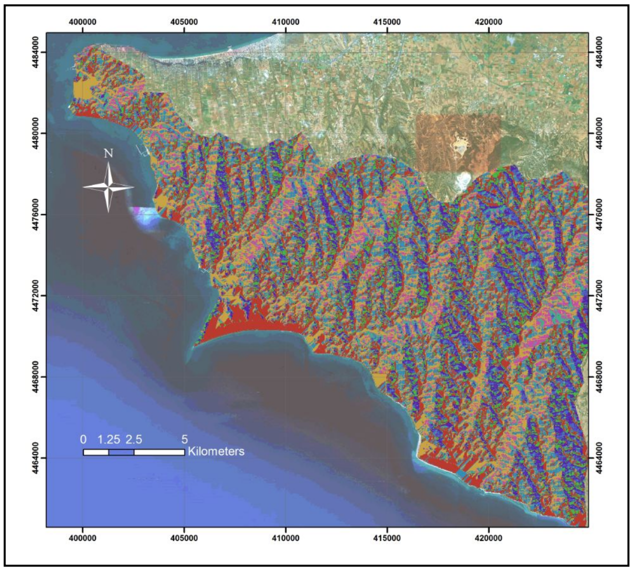


Figure 1: Drainage pattern extracted of gdem.

In figure 2a the mapping of the coast line that took place can be seen. Analyzing this image, locate some areas in the north part, where the erosion is very intense because of the wave process. Furthermore, a difference between the points and the satellite image was observed, after processing data in a GIS. (fig.2b). This happened because of the seasonal growth.

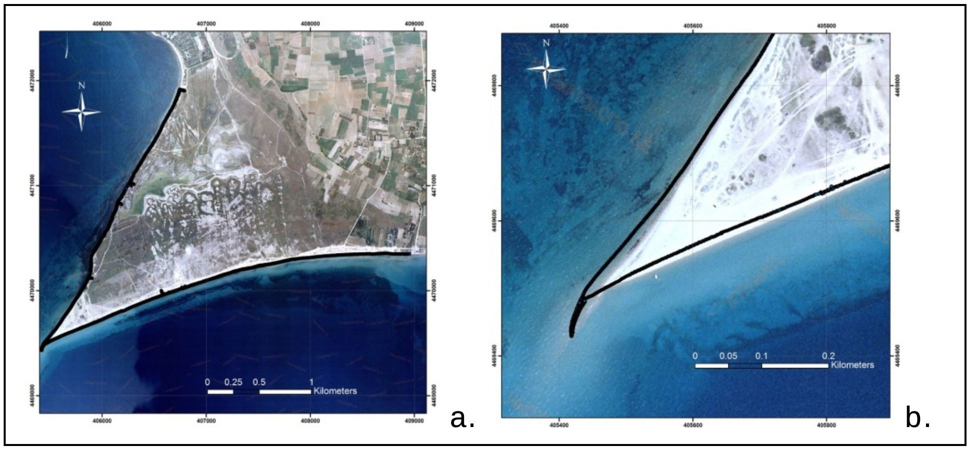


Figure 2: a. GPS points mapping the coast line, b. seasonal growth to the edge of the cuspate foreland.

The main image for the erosion and the sedimentary deposits is that the north part is more prone to erosion than the south part and that can explain the growth of the accretion zone (fig.3a).

In addition, with the GMS-2 the boundaries of the lagoon were mapped. During summertime the lagoon shrinks in a very small part of the cuspate foreland, but during winter most of the cuspate foreland is flooded. (fig.3b) This procedure happens in the summertime. To comprehend the expansion of the lagoon during winter, when the area is too marshy to approach, a vegetation index is being used.

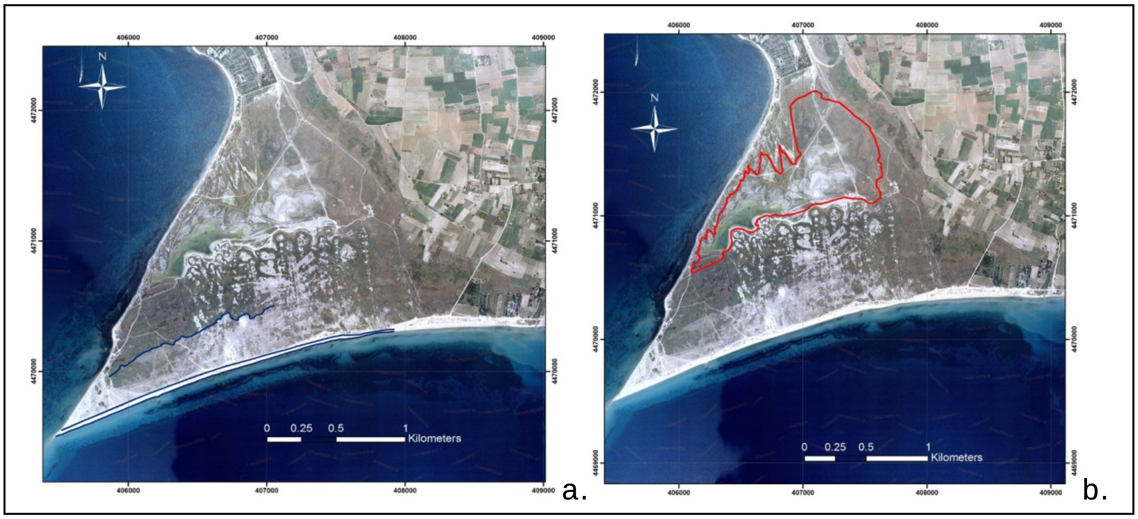


Figure 3: a. Accretion zone, b. Boundaries of lagoon.

Dunes

A variety of dunes has been recorded. In the north part of the area, some parabolic dunes that have been recorded are flat and, as a result, they can be visible only through satellite image and not from the coast. The main axis of these dunes is oriented from north to northwest (fig.4). According to Albanakis (1985) and the diagrams of Thermaikos Gulf winds, the main wind of the area is north and that explains why the dunes have this orientation (Davidson-Arnott, 2010).

Figure 4: Parabolic dunes.

Another type of dunes found on the edge of the foreland is a type of secondary dunes, which are mapped (fig. 5a, b) and from the points an elevation map was extracted (fig. 5c). Along the north coast there are some secondary dunes too, but less high than the dunes close to the edge.

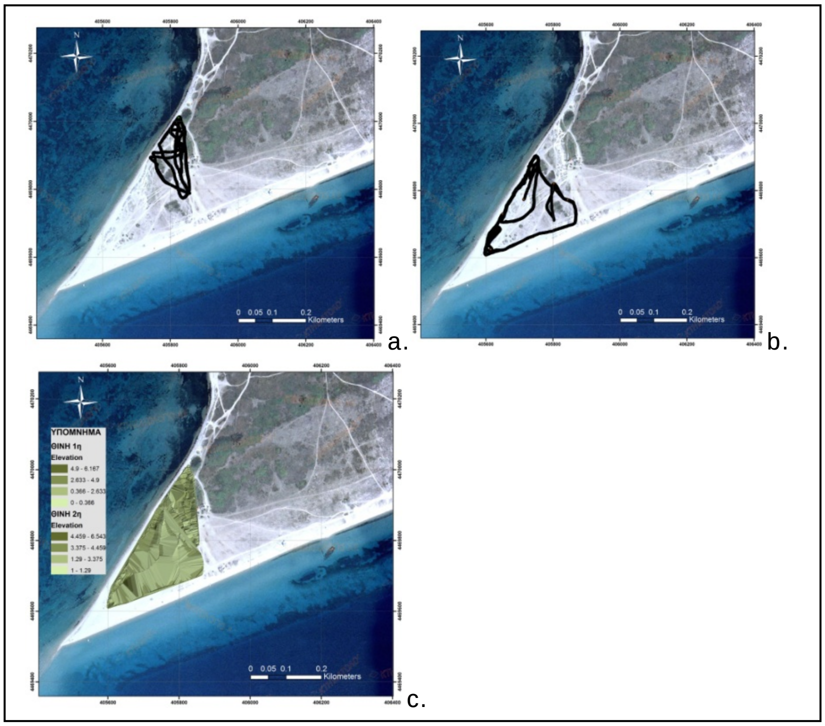


Figure 5: a.b. Secondary dunes close to the edge, c. Elevation map of the secondary dunes.

The last type of dunes that can be found in Mytikas are the embryotic dunes that appear in the south side. They were recorded after monthly observation, because they are so thick and small that they are prone to breaking and spreading their material in the main land (Hesp, 1983).

Lagoon environment

According to Kjerfve (1986), coastal lagoons are subdivided into three different types (fig.6) the type that better matches the environment of the study is the one with the elliptic shape, the vertical orientation to the coast and one entrance, named Chocked lagoon. From the satellite image it became clear that currently there is no entrance because it is blocked by deposits. Locals claim that the part of the lagoon that is close to the coast, was open 40 years ago. This theory is confirmed by the electrical tomographies, as it will be further analyzed below.

Figure 6: a. Choked lagoons, b. Restricted lagoons, c. Leaky lagoons (Kjerfve, 1986).

ELECTRIC RESISTIVITY TOMOGRAPHY

Electric resistivity tomography is a geophysical technique for imaging the sub-surface structures with electrical resistivity measurements that were made in the surface. Electrical methods are divided into the following categories: resistivity method, induce polarization method, physical potential method and the method of telluric currents. These methodologies are further divided in two general categories: the measurement of electrical quantities of natural electric currents or fields, and those based on artificial electric currents or fields (Papazachos, 1986).

Resistivity measurement can be done with electrodes (steel rods) placed in the ground, connected with a cable which is drained by current. The result of this technique is to export a profile of the electric resistivity of the structures under the surface, in a specific depth. There are different types of tomographical arrays. These arrays give a different combination of the current electrodes and the voltage measurement electrodes. Sequence array could be dipole – dipole, pole – dipole, verner – Schlumberger, gradient.

For this project, dipole – dipole array was used for all tomographies. Three tomographies were done in the area, 1km each. Two of them were held at the bottom of the cuspate foreland, starting from the coast and ending in the inland. The third one was held in the mainland and its image was more resistant. In fig.7 there are the three extracted images and in fig. 8 there is a map with the orientation of the tomographies.

Tomography No1 (fig.7, No1) was held in the south part of Mitikas with orientation from south – southeast to north – northwest. From the extracted image after the inversion, it is clear that there is a layer with low resistivity which is saturated with salty water. Its length is 549m and its depth 50m. This saturated material could be silt with sand.

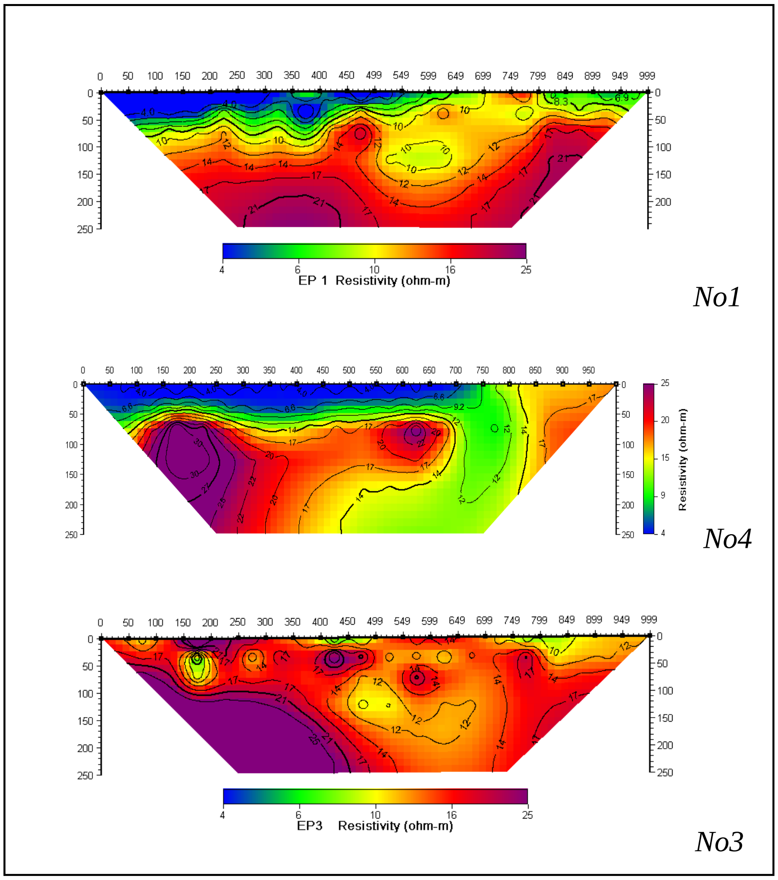


Figure 7: Electric resistivity tomography's of 1Km.

Figure 8: Map of the study area with red array is the ERT location that took place.

Tomography No 4 (fig.7, No4) was held in the north part of Mitikas with orientation from west to east. From the extracted image, the saturated layer can be identified, with low resistivity (blue colour), length

700m and depth 50m. An important observation that was made during this research was a geological discontinuity in the east part of the tomography.

Tomography No3 (fig.7, No3) was held close to the boundary line between Mitikas and the mainland, with orientation from southwest to northeast. The extracted image shows a completely different view from the two previous tomographies. The reason is that the resistivity shows a sudden increase from this section, probably because the material in the area is sandstone, or another material with high resistivity levels.

Two more tomographies, 250m, were held. One, close to the probable entrance of the lagoon (fig.9 No6) and another one at the north east of the lagoon, where the summery coast line of the lagoon is (fig.9 No5). From the extracted image of tomography No5, horizontal alternate layers with different resistivity values were located, which are the result of a calm environment, without many disturbances of wave reaction or wind. In the first 13m, there is a saturated layer with very low resistivity, where the material is silty sand, saturated with sea water.

The next tomography, No6, was held next to the entrance of the lagoon, as it was indicated from locals. The extracted image is completely different from the previous ones and it somewhat verifies locals' claims. In the image, there is a lens of high resistivity (red color) on the surface, which is the developed dune, and underneath there is a layer of low resistivity. Therefore, we can draw the conclusion that this is the aquifer which links the sea to the lagoon and could be the reason why the lagoon floods with water during summer in this area. As a result, this bulk of water doesn't evaporate as other parts of the lagoon do.

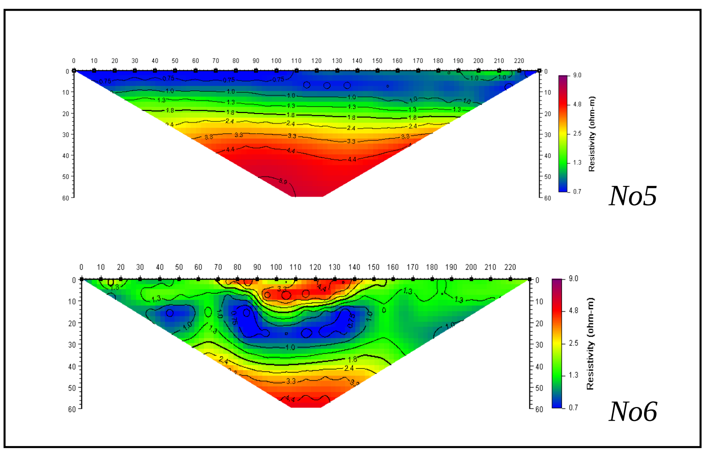


Figure 9: ERT images of 250m tomographys

The last survey that took place in the area included five tomographies of 120m, in the flood part of the lagoon (fig.10a).

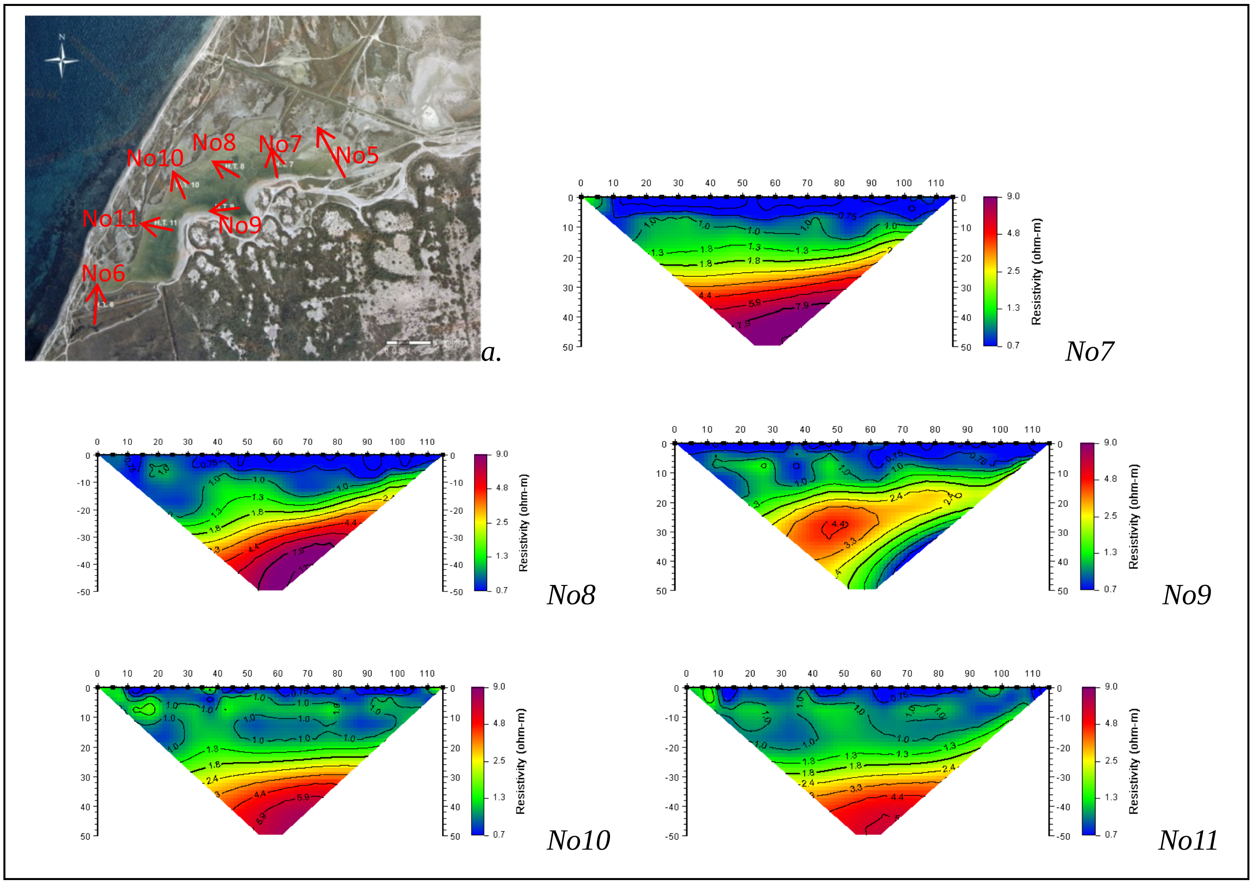


Figure 10: a. Map of the ERT that took place in the flood lagoon, No7 to No11 extracted ERT images.

The orientation of these tomographies is south north, southeast – northwest. The main view of the inverse images is the existance of the horizontal layers and the first 15m low resistivity upper layer in the five tomographies. In tomographies No8 to No11, another layer of low resistivity appears between -10m and -20m. The correlation of these images with tomography No6 and the layer in it between -10m and -20m, proves that this layer is linked to the lagoon.

From the tomographies in the lagoon, a difference of 1.8ohm in the resistivity values has been recorded, which indicates different environments. A map for the same resistivity contour of 1.8ohm with different depths was created (fig.11b) because the 1.8ohm resistivity is not on the same level in all the tomographies. As noted on the map, close to the entrance the depth is quite big, -39, and as it goes further to the north northeast of the lagoon, it develops two higher steps and a draught. The same philosophy that was used for the resistivity contour of 1.8 ohm, was also used to create the map (fig11a) of 1.2ohm which shows the same view. To sum up, there is a big depression at the entrance, followed by two high resistivity points, between which there is another depression. After the second high point, resistivity values are low again.

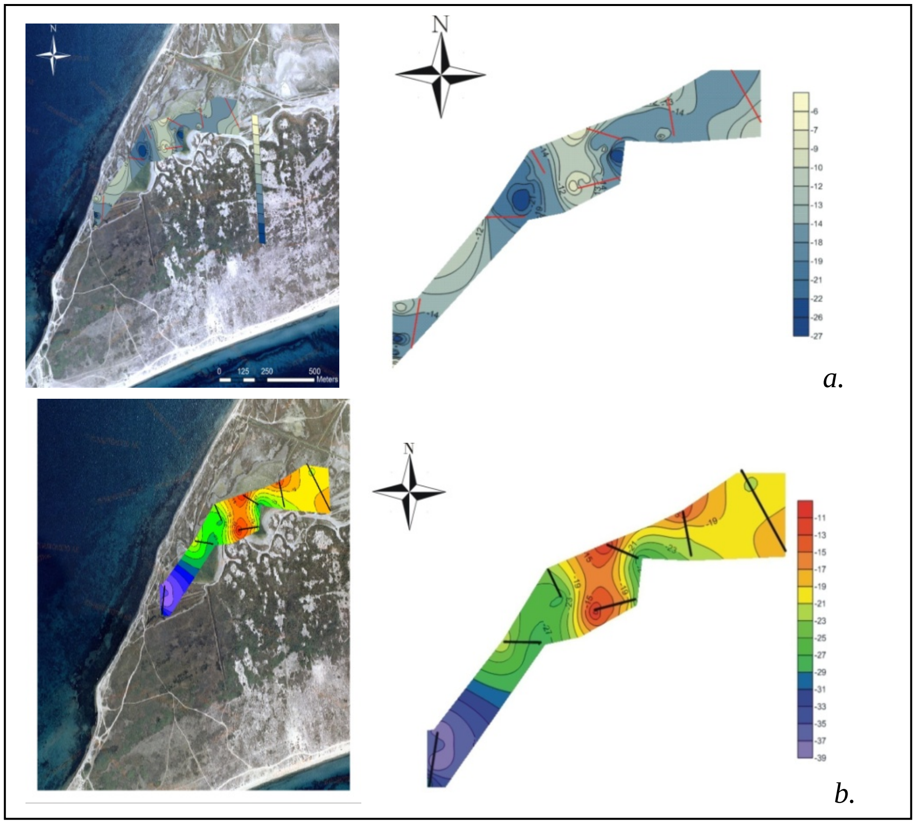


Figure 11: a. Map of 1,2Ohm extracted from the 1,2Ohm resistivity contour, b. map of 1,8Ohm extracted from the 1,8Ohm resistivity contour.

These maps, except for the resistivity, also show the stratigraphy of the lagoon and the thickness of the sediments. According to the map of resistivity 1.2ohm, if we accept the depth of the sedimentary and with the help of the curve sea level rise of Thermaikos Gulf (Vouvalidis et al., 2005) (fig.12.) the age of the lagoon can be estimated at 8000Ybp.

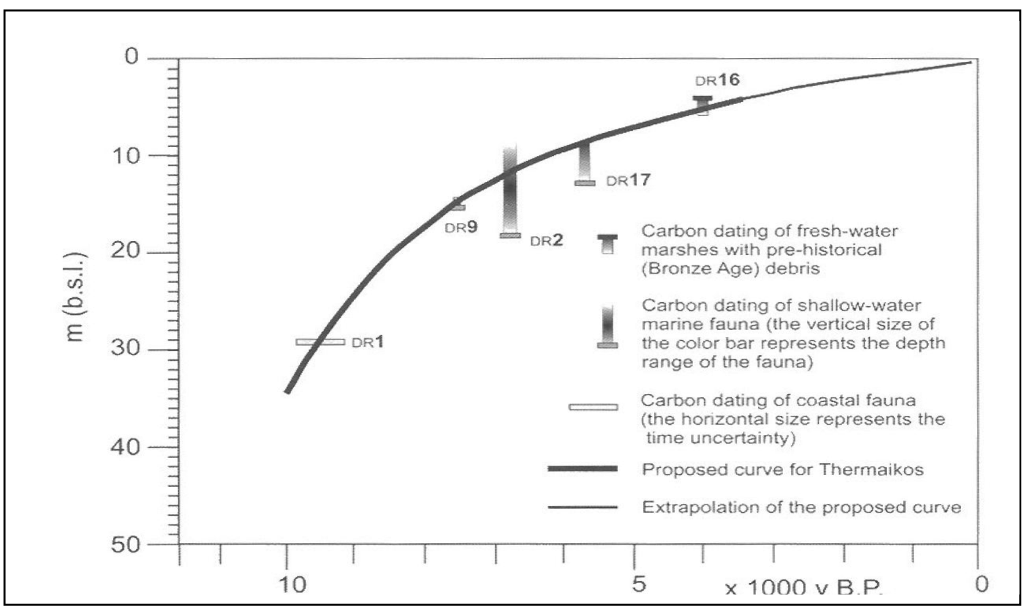


Figure 12: Diagram of the curve sea level rise of Thermaikos Gulf (Vouvalidis et al., 2005)

With the diagram “the sea level rises” (Lambeck and chapel, 2001) (fig.13) and with the tomographies No1 and No4 that show a layer in 50m depth, possible Holocene deposits, the age of the entire cuspate foreland can be estimated at 12000yBP.

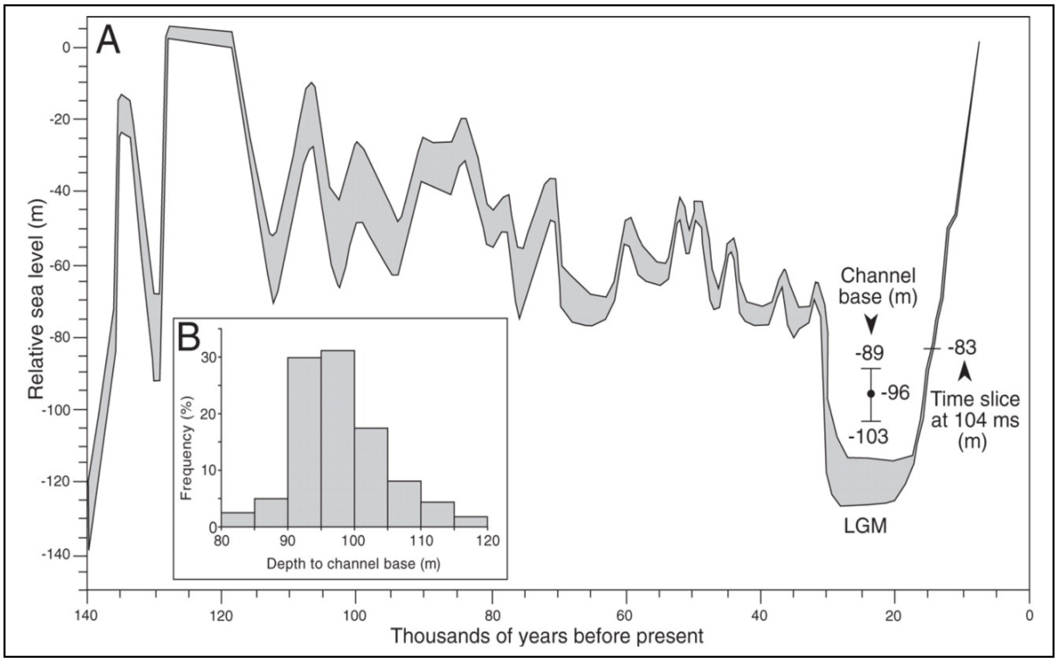


Figure 13: Diagram of the sea level rises (Lambeck and Chappell, 2001)

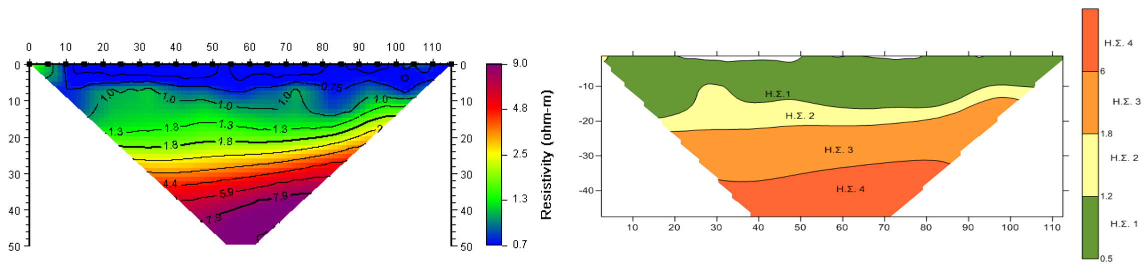
Interpreted tomographies

Since there were no core samplings for this survey, the interpretation of the tomographical images has been done through the already known resistivity values of the materials. Below, there is the table with the classification of the materials (Tab.3).

Each tomography is divided in four different layers according to the electric resistivity contours that give a different environment. The resistivity of these electrical layers ranges from 0.4ohm to 1.2ohm for the upper layer with fine grain sediment, from 1.2ohm to 1.8ohm for the layer underneath with semi grain sediment, for the third layer from 1.8ohm to 6ohm consisted of sand, and for the bottom layer resistivity values were measured less than 6ohm for grit sand.

Table 3: Correlation ERT images and the stratigrafy.

Electric layer	resistivity(Ohm-m)	Color	Possible Sedimentary
E.L. 1	0.4-1.2		Fine grain sediment
E.L. 2	1.2-1.8		Semi grain sediment
E.L. 3	1.8-6		sand
E.L. 4	6<		Grit sand



CONCLUSIONS

The result of this research is a cuspate foreland with 9Km perimeter. The area is almost flat, with a variety of geomorphological features, which are included in this type of environments. Four different zones exist in this environment: coastal zone, accession zone, dune zone and the lagoon environment. Coastal zone consists of sand. The relief is low, with altitude from 0.5m to 1m. The length of the coasts are in the south part 6m to 6.5m and in the north part 15m to 16m. The results of the sedimentological analyses indicate a sandy coastal environment. The recorded accretion zone in the south part concludes that the conditions in the south part are more stable and not too windy, so the wave processes don't affect remarkably the coastal deposits and thus, the accretion zone has the opportunity to develop. The results of the sedimentological analyses indicate a moderately to well classified environment.

There are some seasonal movements on the edge of the cuspate foreland because of the seasonal wind and it is possible that the amount of the material in the south part is more than in the north part.

According to the diagram "the sea level rise" by (Lambeck and Chappell, 2001), this is a recent geomorphological feature. Its age was estimated at 12000yBP, unlike the lagoon, that is the latest feature developed (8000yBP). This result was extracted by "the sea level curve rise" of Thermaikos Gulf (Vouvalidis et al., 2005). These conclusions were drawn from the electrical resistivity tomographies that were held in the research area.

The results of the sedimentological analyses record materials like sand and sandstones. Except for the recognized material, another fact is that this area is active and new deposits are being added over the years.

Except for the typical geomorphological features of the main dunes along the south coast, and some appearances in the north coast, there are also some secondary dunes on the edge of the cuspate foreland, with the highest elevation and some parabolic dunes in the south coast which were configured from the south main wind. The sedimentological analyses of the dunes samples shows well sorted, symmetric and mesokurtic sand.

A very important part of the cuspate foreland is the lagoon that is included in this environment. It is an ecosystem that hosts many kinds of fauna and flora. According to locals, as previously mentioned, the entrance of the lagoon 40 years ago was open and linked to the sea, but nowadays it is closed because of the coastal deposits. The entrance is located in the north coast.

From the digitization of the drainage pattern, we reached the conclusion that the study area is between two torrents, although none is linked to the lagoon. Because of the very low altimeter of the area, it is highly possible that the rain during winter causes the lagoon to flood.

The perimeter of the lagoon during winter is 5.5Km. The material is very fine clay, as it results from the Pipette analysis, and organic-rich material, which explains why the environment is marshy. Moreover, because of the fact that the lagoon is cut off from the sea, the wind is slight and the waves have weak reaction to the coast. The reflection of the waves appears to have round formations throughout the year.

FURTHER RESEARCH

This work for the cuspate foreland Mitikas in Epanomi, raised new questions for future research. The combination of many geological procedures will give more details about the procreation of this feature, which is an ecosystem with many species of fauna and flora that could be further studied. There is a place, where the geomorphological procedures happen in real time, so a researcher could study them while observing them.

A more detailed research that could be conducted after the electric resistivity tomographies, is the operation of scientific drillings in specific positions. The coring samples of invertebrates could be collected and analyzed with radiocarbon in order to confirm the age of the lagoon and the cuspate foreland.

A new sedimentolodical sampling could give the oryctological component with XRD and XRF analysis.

Finally, a new research on the sea bed in the north and the south part of the area will provide a better image of the beach rock and how it procreates, as well as the depth under the sediments and their length.

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