A Contribution To Environmental Research of the Korissia Coastal Wetland (Corfu isl., Greece), with the Application of Combined Geological and Geophysical Methods supported by Geographic Information Systems

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ABSTRACT

In the current paper are presented the results of a multidisciplinary study (stratigraphical, sedimentological, geophysical and geochemical) combined with modern techniques (G.I.S. and remote sensing). This study aims at integrating the natural and anthropogenic factors affecting the Korissia lagoon. It is a shallow coastal lagoon, communicating with the sea via an artificial channel. The area around the lagoon consists of alluvial sediments hosting, in places, newly formed and/or "old" (pre Holocene) sand-dunes. The broader area constitutes a post-alpine sedimentary basin characterised by smooth morphological relief. The lower stratigraphic unit of the post-alpine sequence is a Pleistocene marly formation, which was detected as the basement (5-15 Ohm.m) by the geophysical survey. The resistivity-based basement map implies the existence of a "palaeo-gulf" trending E-W. These marls constitute the impermeable basement of a shallow aquifer hosted in the area. The salinity of the lagoon is very high during summer (>40psu) but it does not affect significantly the wells around it. The lagoon is well oxygenated, while the wells have lower D.O. values. Ammonia and nitrates are the main inorganic Nitrogen forms, in the lagoon and the wells, respectively. Phosphorus is the limiting factor for phytoplankton growth. Human activities affect the area that is in need of an environmental management plan in order to prevent ecological degradation.

ΠΕΡΙΛΗΨΗ

Στην παρούσα εργασία παρουσιάζονται τα αποτελέσματα μίας πολυπαραμετρικής έρευνας (στρωματογραφικής, ιζηματολογικής, γεωφυσικής και γεωχημικής), σε συνδυασμό με τη εφαρμογή σύγχρονων τεχνολογιών (Σ.Γ.Π. και τηλεπισκόπηση). Στόχος της έρευνας είναι η αποτίμηση των φυσικών και ανθρωπογενών παραμέτρων, που διαμορφώνουν το γεωπεριβαλλοντικό καθεστώς της Λιμνοθάλασσας Κορισσίων. Πρόκειται για μία ρηχή παράκτια λιμνοθάλασσα, που επικοινωνεί με τη θάλασσα μέσω ενός τεχνητού διαύλου. Η περιοχή καλύπτεται κυρίως από αλλούβιες αποθέσεις, ενώ κατά τόπους απαντούν πρόσφατες ή/και «παλαιές» (προ-ολοκαινικές) θίνες. Η ευρύτερη περιοχή αποτελεί μία μεταλπική λεκάνη ιζηματογένεσης, ήπιου γενικά μορφολογικού αναγλύφου. Την κατώτερη στρωματογραφική ενότητα της λεκάνης αποτελεί μία ακολουθία μαργών, η οποία από τη γεωφυσική έρευνα που πραγματοποιήθηκε, αποτελεί το γεωηλεκτρικό υπόβαθρο (5-15 Ohm.m). Η μορφολογία της επιφάνειας του γεωηλεκτρικού υποβάθρου υποδεικνύει την ύπαρξη ενός «παλαιοκόλπου» στη σημερινή θέση της λιμνοθάλασσας. Οι μάργες αποτελούν το αδιαπέρατο υπόβαθρο του φρεατίου υδροφόρου ορίζοντα, που αναπτύσσεται στα υπερκείμενα ιζήματα. Η αλατότητα της λιμνοθάλασσας, που εμφανίζεται ιδιαίτερα αυξημένη το καλοκαίρι (>50 psu), δεν επηρεάζει την ποιότητα του υδροφόρου ορίζοντα. Η λιμνοθάλασσα παρουσιάζει καλή οξυγόνωση, ενώ οι τιμές διαλυμένου οξυγόνου στα πηγάδια είναι χαμηλότερες. Η αμμωνία και τα νιτρώδη είναι οι κύριες μορφές ανόργανου αζώτου, που απαντούν στη λιμνοθάλασσα και στα πηγάδια, αντίστοιχα. Ο φώσφορος αποτελεί περιοριστικό παράγοντα για την ανάπτυξη του φυτοπλαγκτόν. Οι ανθρωπογενείς δραστηριότητες επηρεάζουν την περιοχή, για την οποία πρέπει να εφαρμοστεί ένα περιβαλλοντικό σχέδιο διαχείρισης, προκειμένου να αποφευχθεί η υποβάθμισή της.

Figure 1. Panoramic view of the study area. The narrow barrier which is separating the lagoon from the sea is very clear at the middle right of the photograph. The relatively planar topographic relief to the left is rising very suddenly to the right where the Kavalovouni hill is starting to form.

Figure 2. Elevation map and shaded relief of the study area created by the interpretation of high resolution digital elevation model. The main channels of the drainage network are also shown in the watershed around the lake area. The three high detailed topographic surveys are also marked in red.

The Korissia lagoon (Fig. 1) is elongated in shape (5300 m long and 1500 m wide) located parallel to the shoreline having a NW-SE orientation (Fig. 2). It is a shallow lake, with water depths below 1.5 m and connected to the sea via a narrow (8 m) and shallow (<1 m) artificial channel (Fig.3a). Moreover, the coastal exit of the channel is protected from the waves by artificially placed breakwaters.

It is separated from the open Ionian Sea by a strip of land, up to 200 m wide, which can be distinguished into two parts: a part southwards the channel which consists of uplifted Plio-Pleistocene formations, including "old" sandy dunes with maximum elevations up to 15 m and an elongated deposit northwards the channel, that is essentially a beach barrier hosting lower recent sand dunes, reaching up to 2 meters height (Fig. 11). In addition, at the foot of the "old" (pre-Holocene) high dunes, modern dunes have been developed, whilst the presence of beach-rock formations along parts of the beach face indicates mixing of fresh and sea water (Fig.3b).

Image interpretation of remote sensing data (Fig. 10) and analysis of high resolution DEM (Fig. 2) were used for extracting geomorphological and geological information. They were also used for creating background images in a GIS designed for gathering, organizing and managing the different kinds of data.

Three (3) topographic high resolution profiles (at 20m intervals) were carried out across the strip of land that separates the lagoon from the Ionian Sea, with the use of handheld GPS and topographic rods (Fig. 4). Along these profiles superficial sediment samples have been collected and analyzed according to Folk's (1974) procedure.

Figure 11. The contemporary dunes (d1) covering most of the area between the Ionian sea and the Korissia lake are creating a natural barrier between the two water bodies.

The alpine basement of the area consists of sediments belonging to the Ionian tectono-stratigraphic unit (Aubouin, 1959, Jacobshagen, 1986) of the external micro-plate of the Hellenides (Papanikolaou, 1997). At the broader area of the Korissia lagoon, only part of the Ionian stratigraphic column is exposed (Fig. 15).The major part of the alpine basement is covered by younger sediments which create a relatively impermeable layer beneath the formed lake.

Tthe oldest post alpine sediments exposed around the lagoon area are of Pleistocene age (Rogl et al, 1997). The lower stratigraphic unit is a marine to brackish, predominantly grey, marly to clayey sedimentary sequence, lying unconformably over the alpine basement. The sequence is continuing with a 10 m thick sandstone layer deposited over the 12 meters thick marls, ending with a thin sapropel layer of Late Pleistocene age. The sequence is slightly folded by open folds with E-W axis direction. Above these beds lies a formation dominated by siliciclastic sandstones, sands, and gravels, followed by a zone with fossiliferous cavernous, calcareous sandstones (corallinacean - packstone) of Late Pleistocene age. Several fault blocks can be identified and seem to compose the area, separated by recently activated fault zones that caused tilting towards NE (Fig. 12).

The aforementioned post alpine successions are covered by cross bedded sand dunes (Fig. 11). The older dunes (Fig. 13) are found at higher altitudes parallel and adjacent to the tectonic contact between the alpine basement and the recent deposits (Fig. 14a). The most recent dunes are located along the southern coastline, a forming a beach barrier that separates the lagoon from the Ionian sea. The unconformity is clear at the beach of Richoneria (Fig. 14a) where also beach rocks are currently formed along the coastline (Fig. 3).

Figure 12. In this view of the coastal area towards SE, a large part of the Late Pleistocene sequence of marine sediments seems to have been tilted to the NE. This block tilting has resulted the uplift of the SW coast and therefore the rising of the impermeable basement of the Korissia lake, separating the sea from the fresh water table.

Figure 13. The older sand dune beds (d2) crossing each other, are revealed on the top of the hills near Mesa Vrysi and Plymmata locations. The altitudes on which they are found are relatively high (, as they were supposed to be near the coastline during their sedimentation procedures. This is a clue of the recent uplift of the coastal area and the Korissia lagoon, caused by the fault zones trending WNW-ESE.

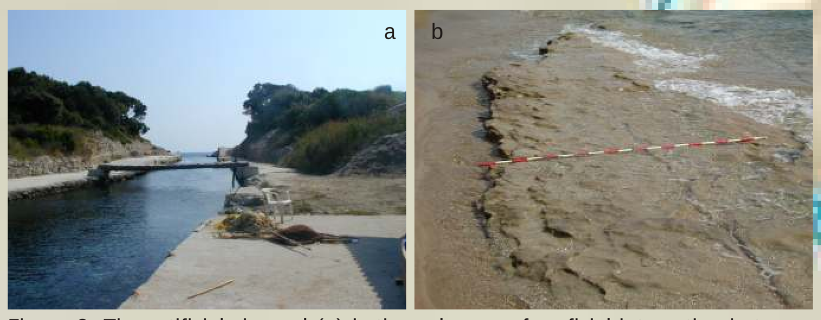


Figure 3. The artificial channel (a) is the only way of surficial interaction between salted and fresh water. There are also regions where beachrocks (b) are formed, possibly because of the underground mixture of the sea and the groundwater.

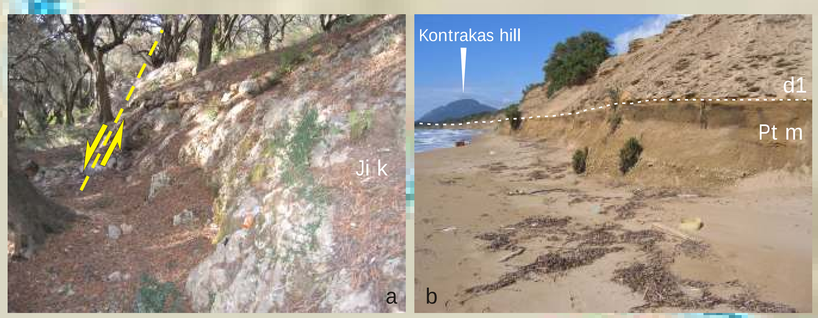


Figure 14. Fault surface with normal kinematic indicators at the southern prone of Kontrakas hill on the alpine carbonate rocks (Ji k) of Ionian unit (a) and (b) the unconformity between Late Pleistocene marine series (Pt m) and the contemporary dunes (d1) along the coastal area at Richoneria.

Figure 4. The three topographic sections carried out in the land strip that separates the lagoon from the sea were extended nearshore.

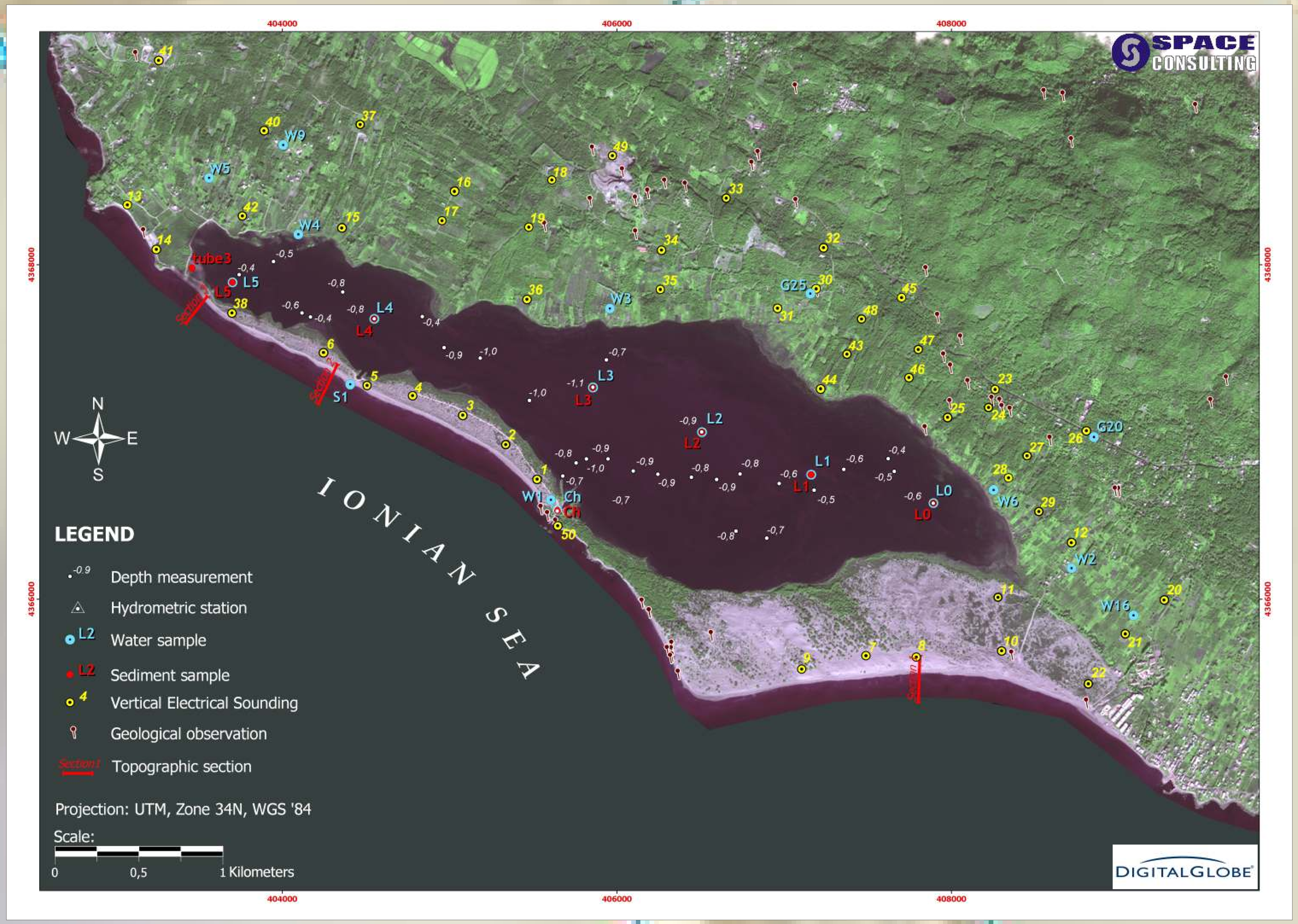


Figure 10. Very high resolution satellite images (Quickbird, Ikonos) acquired at different time periods were used and combined with remote sensing data from several sensors with different spectral and spatial specifications (Landsat 5 - TM, aerial photographs). Thus many of the temporal changes of the region such as land use, the coast of the lagoon etc, were identified. In addition pictures created after spectral analysis and interpretation were used as background images in the G.I.S. that was designed for gathering the collected data from all the research teams working in the area. The area was studied in much detail by creating a very dense grid of sampling sites for a complete environmental research.

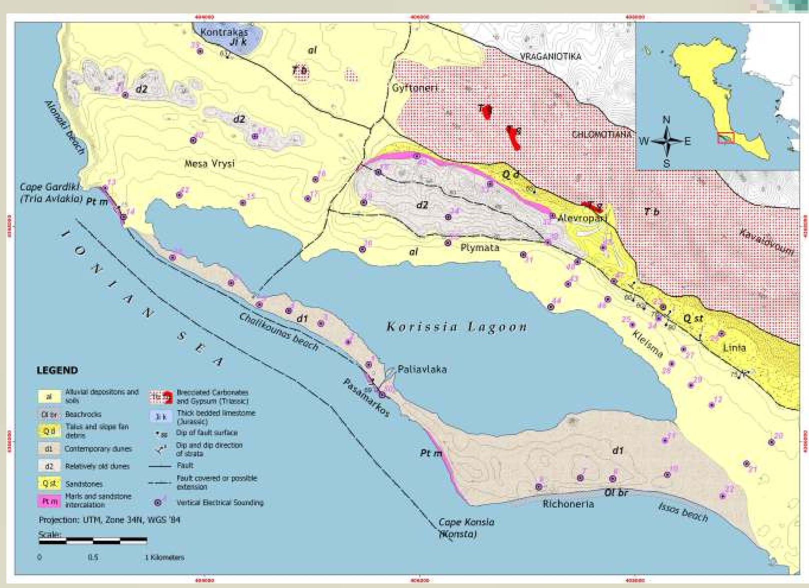


Figure 15. The geological map of the wider area surrounding the Korissia lake was the result of the field work and used for preparing the geoelectrical campaign. The spots for the electrical soundings were selected in such way to give more answers for the tectonic regime of the area and consequently provide important information for the groundwater depths and the environmental management of the lagoon.

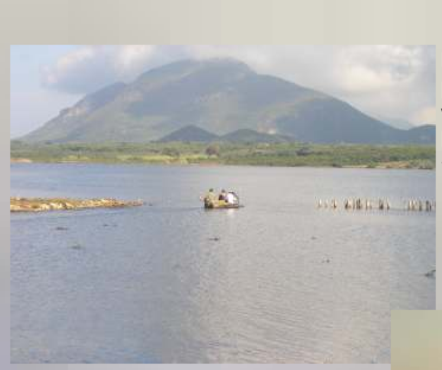


Figure 5. A boat was provided by the people working in the aquaculture. The water and sediment samples from the bottom of the lake were collected with their contribution.

Figure 6. Undisturbed sediment samples for laboratory tests and analysis were collected from the lagoonal area with the use of plexiglass sampling tubes.

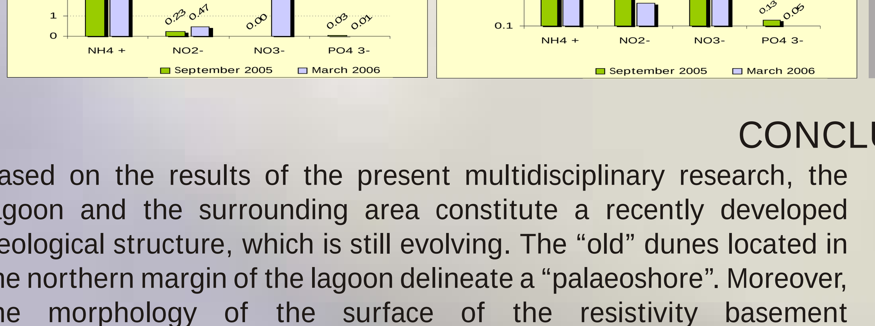
Figure 7. Sediment samples from the bottom of the artificial channel were recovered with the use of a Van Veen grab.

Figure 8. Weather data were collected by portable meteorological station which was set up in the area during the fieldwork operations.

Figure 9. Sediment cores reaching 4 meters depth were extracted near the shore of the lagoon, using portable borehole equipment.

Sediment and water samples were collected from the lagoon (Fig. 5-6), the communication channel (Fig. 7-9) and the open sea near the exit. Subsurface water samples were also collected from wells around the lagoon. A small quantity of chloroform was added to each sample for nutrient preservation. The samples were filtered by Millipore nitrocellulose filters (8μm and 0.45μm) and stored in a refrigerator. Temperature, salinity, conductivity and dissolved oxygen were measured in situ by YSI63 and YSI 550A portable instruments. Ammonia, nitrites, nitrates and phosphates were measured spectro-photometrically (Grasshoff et al., 1999). The results of the water samples' chemical analysis at the diagrams below, show the seasonal and regional fluctuations of the various forms of nitrogen and phosphorous in surface and subsurface waters. Ammonia is the main inorganic N form in Korissia lagoon whereas nitrates are the predominating N form in the wells around the lagoon. Phosphates values in the lagoon were very low.

Several sediment samples were collected on September 2005 with the use of a Van Veen grab (Fig. 7). Most of the lagoon's bottom was covered by grass and the samples contained large numbers of shellfish. The sediment samples were freeze-dried, dry sieved and analysed for Total N and Total P (Ladakis et al., 2003).



Fifty (50) Vertical Electrical Soundings (VES) were carried out in the area around the lagoon, in order to investigate the stratigraphic structure of the subsurface geological formations, underlying the study area. In order to overcome the limitations imposed by the absence of borehole data, a number of five (5) in situ measurements (VES No 23, 30, 41, 49 and 50) were carried out at outcrops of the main geological formations (Fig. 18). Thus, representative resistivity values were obtained to be used for the interpretation of geoelectrical soundings.

All soundings were performed by applying the Schlumberger array configuration. Maximum current electrode spacing (AB) reached up to 430 meters. Current electrode spreading operation met difficulties due to the occasionally steep relief, the dense vegetation and district construction (streets, residences, fences, etc). A Terrameter SAS300B with Booster (ABEM) was used for these measurements.

The geophysical data processing and interpretation was realised by applying the automatic method of Zohdy and Bisdorf (Zohdy, 1989), implemented by the software DCINV proposed by Markku Pirttijdrvi (2004) and the commercial package WinSev6.1 of W-GeoSoft, with very good results.

In almost all soundings, a formation with resistivity values between 5.0-15.0 Ohm.m was detected. In situ measurements in marl outcrops (VES 49 and 50), yielded resistivity values between 5.5 and 13.0 Ohm.m.

The formation of 7.0-9.0 Ohm.m is considered to represent the basement, corresponding to the lower stratigraphic unit of contemporary basin in the investigated area. Thus the geophysical data were very useful for the generation of a subsurface map of the top of the impermeable bed sequence (Fig. 16).

Figure 16. Resistivity basement map based on VES interpretation and geological mapping. This is also a subsurface map of the top of the impermeable marly formation which represents the end of the open marine cycle at the lagoon area.

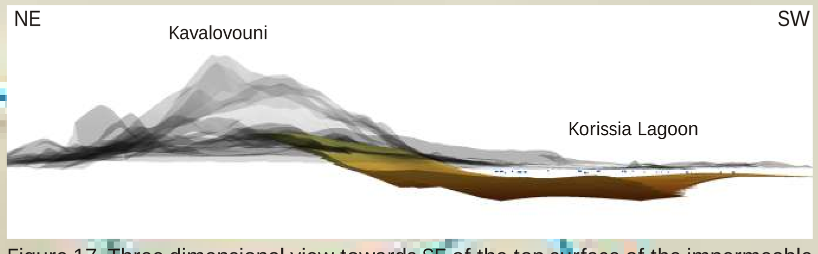


Figure 17. Three dimensional view towards SE of the top surface of the impermeable basement (colored plane) under the lagoon. The vertical exaggeration (x5) of both landscape relief (gray) and subsurface allow the distinction among the two, as they seem to be very close.

Figure 18. Five in situ soundings were carried out at outcrops of the post alpine formations by applying the Schlumberger array configuration.

CONCLUSIONS

Based on the results of the present multidisciplinary research, the lagoon and the surrounding area constitute a recently developed geological structure, which is still evolving. The "old" dunes located in the northern margin of the lagoon delineate a "palaeoshore". Moreover, the morphology of the surface of the resistivity basement (impermeable marly sequence), also supports the existence of a former narrow gulf, trending E-W. The SW part of the contemporary land strip, separating the sea from the lagoon, is associated with the earlier existence of a beach barrier.

Today, the lagoonal waters are strongly affected by freshwater inputs, especially during winter time, whilst during the summer period the influx of sea water and the excess of evaporation over precipitation make salinity values higher (>45 psu) than those of the Ionian Sea. Moreover, human activities and mainly agriculture influence the lagoon's chemistry. The latter is also related to the aquatic flora. Accordingly, nutrient values in the lagoonal waters increase from autumn to late winter (wet period), while the opposite trend is observed in groundwater during the same period.

The Korissia lagoon is an interesting and fragile coastal wetland and needs further study and continuous monitoring in order to avoid possible environmental degradation and to ensure its sustainable exploitation; whilst the latter can only be achieved through the implementation of an environmental management plan based upon the obtained scientific knowledge.

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GEOCHEMISTRY - SEDIMENTOLOGY - GEOMORPHOLOGY

GEOlogy - tectonics - applied geophysics