ΔΕΛΤΙΟ ΤΗΣ ΕΛΛΗΝΙΚΗΣ ΓΕΩΛΟΓΙΚΗΣ ΕΤΑΙΡΙΑΣ
BULLETIN OF THE GEOLOGICAL SOCIETY OF GREECE

ΤΟΜΟΣ XXXII, No 1 *VOLUME XXXII, No 1*

8° ΔΙΕΘΝΕΣ ΣΥΝΕΔΡΙΟ της ΕΛΛΗΝΙΚΗΣ ΓΕΩΛΟΓΙΚΗΣ ΕΤΑΙΡΙΑΣ

με έμφαση στην Περιβαλλοντική Γεωλογία

8th INTERNATIONAL CONGRESS of the GEOLOGICAL SOCIETY OF GREECE

with emphasis on Environmental Geology

Πάτρα - Patras

1998

SATELLITE IMAGES OF SHORT WAVELENGTH RADIATION FOR STRUCTURE DETECTION IN SHALLOW WATERS. CASE STUDY: AEGINA - AGISTRI ISLANDS', SARONIKOS GULF.

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ABSTRACT

Satellite images recorded in the visible part of the electromagnetic spectrum could be used in the recognition of medium scale, submarine morphotectonic structures, under certain conditions. After special image processing techniques, the shallow water bottom area was enhanced and helped us connect the structures on both sides of the coastal area. The contribution of remote sensing to the results of neotectonic investigation of the submarine area between the islands of Aegina and Agistri had offered new elements for the determination of new structures and of the causes of their origin.

KEY WORDS: remote sensing, morphotectonic, Landsat, Saronikos gulf

1. INTRODUCTION

Spectral qualities of water bodies are determined by the interaction of several factors, including the radiation incident to the water surface, optical properties of the water, roughness of the surface, angles of observation and illumination and, in some instances, reflection of light from the bottom (Cambell, 1996).

This study describes an effort that was made for detecting structures under shallow waters, using Landsat TM images. The light that enters a water body is influenced by: (a) absorption and scattering by pure water, and (b) scattering, reflection and diffraction by particles that may be suspended in the water.

The transparency of the water happens in a small window between 0.44 and 0.54 micrometers, with maximum transparency to radiation at about 0.48 μm. Under these spectral conditions some solar energy is reflected from the bottom and is possible to be recorded by a satellite. By using the spectral range of 0.45-0.52 micrometers, that is band 1 of the Thematic Mapper, it is possible to detect submarine structures, if the waters are fairly clear and shallow. In clear deep waters 50 percent of the signal that is recorded by the band 1 of the TM, comes from the depth of about 15 meters or less (Abiodun and Oesberg, 1985)(Fig. 1). Because the color of water is determined by volume scattering, rather than surface reflection, spectral properties of water bodies (unlike those of land features) are determined by transmittance rather than surface characteristics alone.

The area between the islands Aegina and Agistri is very suitable for this kind of investigation, as the bathymetry hardly exceeds 15 meters of depth. The penetration of the solar energy is sufficient enough so that the ridge between the two islands can be visualized by Landsat TM image.

The structure between the two islands was not studied and no correlation existed for the morphotectonic structures of the area. The aim of this paper is to link surface and submarine geological observations at the coastal zone, by using remote sensing.

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2. GEOLOGICAL SETTING OF THE AREA

The study area contains the submarine space between the islands of Agistri and Aegina including the rock island of Metopi. Generally, these islands are part of the very shallow N-S zone that divides the Saronikos Gulf into the western and eastern basins (Papanikolaou et al. 1988). This shallow zone comprises several volcanic outcrops of Plio-Quaternary age, representing the northwestern edge of the modern Aegean volcanic arc. Referring to regional scale the authors note that Saronikos Gulf is very complicated and in fact it includes different neotectonic styles. The presence of recent volcanoes in the central area produces an even more complicated structure and at the same time it delineates the active western part from the relatively inactive eastern part. The submarine area is consisted of Plio-Quaternary sediments not thicker than 50 meters (Papanikolaou et al. 1989).

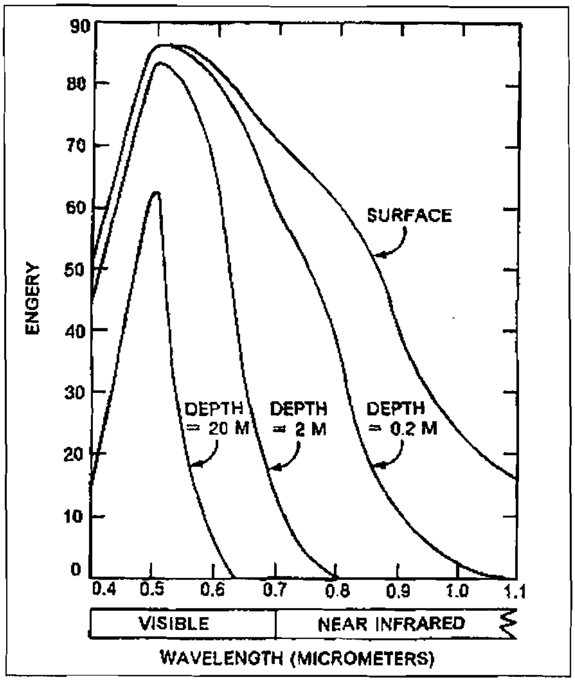

Fig. 1: Spectral characteristics of sunlight as it penetrates a clear water body. Near the surface the curve resembles the spectrum of solar radiation, but the water body increasingly influences the spectral composition of the light as depth increases. At a depth of 20 meters no infrared radiation is present as the water body is an effective absorber of these longer wavelengths. From Moore (1978).

Symeonidis and Dermitzakis (1975) in a geomorphological study about coast-line evolution in the area of Agistri and Metopi islands refer that in the NE of the Agistri island the most common alpine rocks are black, thinbedded limestones, intensively folded and ruptured (Fig. 2). Their age is Late Triassic - Early Jurassic. The post-alpine sediments consists of Pliocene and Pleistocene marl conglomerates and sandstones of moderate thickness. The discordance between the alpine and the post alpine sediments on Agistri is covered by talus scree. The same post alpine sediments crop on the Metopi island, that is located eastward of Agistri. Concluding, the authors note that at the Pleistocene period, the sea water had covered the coasts of the two islands as well as part of Aegina and the proof is a reddish sandstone bed found on all islands. They also note that the shape of the islands was controlled by tectonic movements. Finally they observed ancient settlements at a depth of about 2 meters, between Agistri and Metopi and related this fact not only to eustatic movements but also to tectonic movements. The western coasts of Aegina island lithologically consist of Pleistocene sediments, more or less of the same phases as of the other two islands.

Regarding to Livaditis (1974), Aegina has been affected by neotectonic movements similar to those of the area of Attika.

3. DATA SOURCES

The satellite images used in this research were acquired by the Thematic Mapper instrument on board of Landsat 5 satellite. The TM sensor operates in multispectral mode (7 bands, 30 meters resolution). A digital image was acquired on 7-10-93 from which a subscene including the study area was obtained (665 rows, 794 columns). The topographic maps used, were "MEGARA" and "METHANA" of scale 1:50.000. Also, the "Submarine Neotectonic Map of Saronikos Gulf" (Papanikolaou et al. 1989) was very helpful as the submarine faults of the study area were shown (Fig. 3).

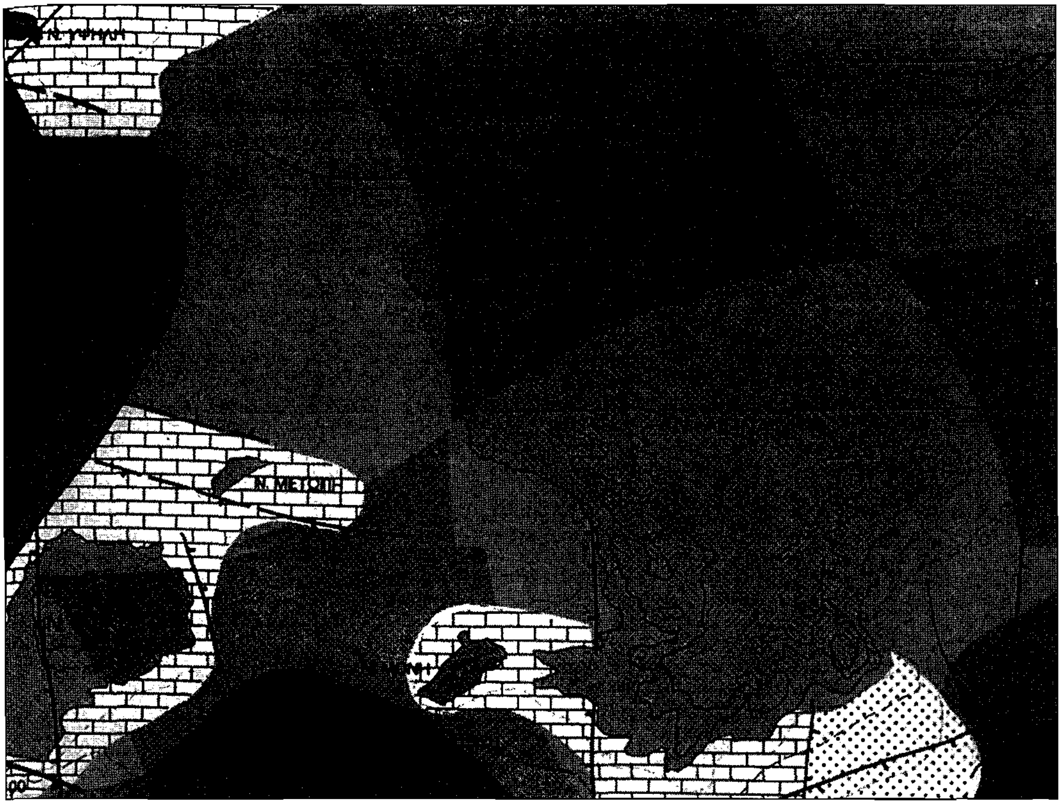

Fig. 2: Submarine Neotectonic map of the Aegina - Agistri area. Continuous seismic profiling was carried out using a 40 in^3 Air-gun. From Papanikolaou et al. (1989)

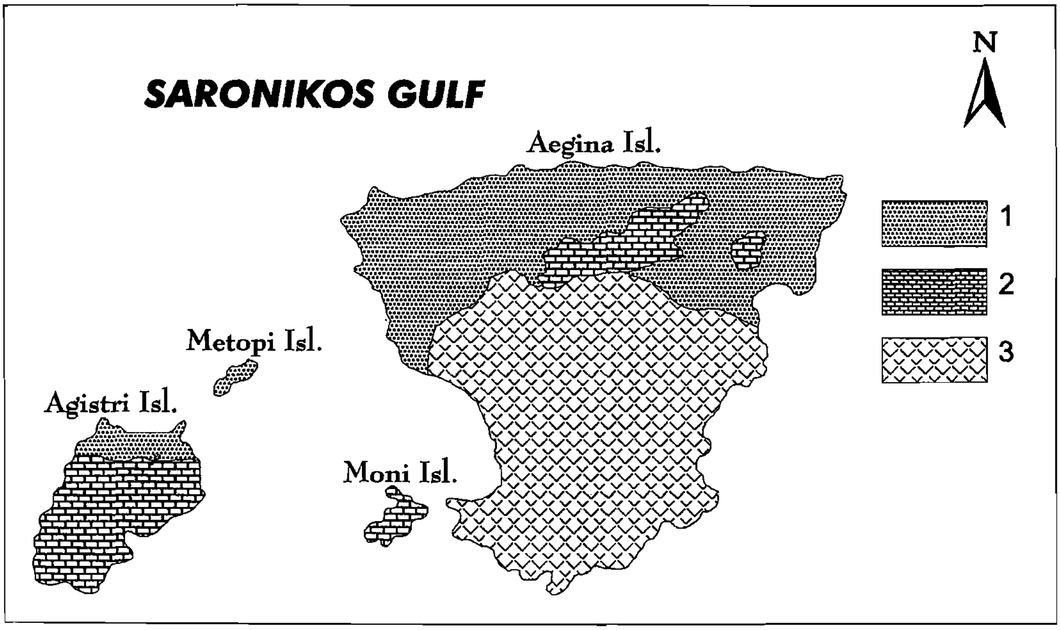

Fig. 3: Simplified geological map of Aegina and Agistri. 1. Postalpine formations, 2. Alpine formations, 3. Volcanic rocks.

4. DATA PROCESSING, ANALYSIS AND INTERPRETATION

The satellite image was processed spatially for texture variables. The image texture refers to the visual impression of coarseness or smoothness caused by variability or uniformity of image tone or color and is one of the basic elements of photo interpretation (Avery and Berlin, 1992).

The first 3 bands out of 7 of the Thematic Mapper were selected, because of their properties regarding to the penetration through the water. The following processing steps were applied using Imagine v. 8.2 of ERDAS in a PC environment:

• Atmospheric correction

The effects of the atmosphere upon remotely sensed data are not considered "errors" since they are part of the signal received by the sensing device (Bernstein, 1983). However it is very important to remove atmospheric effects, especially at the visible channels, as it has been noted that for the visible channels the atmospheric contribution to the radiance, received by a satellite, forms a very much greater percentage of the radiance leaving the target area than in the case of infrared (Cracknel and Hayes, 1991). In this case the haze reduction technique was applied. The method is based on the Tasseled Cap transformation, which yields a component that correlates with haze. The component was removed and the image was transformed back to RGB space.

• Geometric correction

These corrections are applied to raw data to correct errors due to the earth's curvature and sensor motion. After this correction the image has map properties and it is possible to be merged with other vector layers. The correction was made by selecting 14 points along the coast of Aegina and Agistri islands (projection system EGSA87, RMS = 16m, pixel size after resampling = 30m) (Fig. 4a).

• Contrast enhancement

After the linear stretching using the method of Standard Deviation for better contrast enhancement (in this case the minimum and maximum values were too extreme to produce good results), a piecewise linear contrast was applied in order to enhance the area where we have reflection from the bottom. Taking the information of the Digital Numbers of pixels representing the area of the reflected signal, the minimum and the maximum values were stretched and enhanced the particular area (Fig. 4b). After this contrast enhancement technique, the saturation on the grayscale, mainly at the higher Digital Numbers, is observed (see the flat area at the northwestern part of Aegina island).

5. ANALYSIS AND INTERPRETATION

Using the topographic maps of scale 1:50.000, the submarine and surface contours were digitized, for the purpose of showing that the high digital numbers of the pixels between Aegina and Agistri island, are due to morphological causes and not to the properties or quality of the water body.

As originally thought, the high values of the pixels between these islands are representing the submarine ridge that has the shape of the Agistri island continuing to the northeast, bending at the Metopi island to the east and finally creating an S-structure, at the western coasts of Aegina island, where the ridge is bending towards the north (Fig. 5). After, on computer screen, mensuration, the ridge area was found 4.238,22 acres (including Metopi), inside its perimeter that was measured 21,7 km. The major percentage of the ridge was between the sea surface at a depth of 10 meters.

The main faults that have been described by Papanikolaou et al. (1989), are the SW-NE directed submarine faults (one west of Agistri and one north east of Aegina)(Fig. 2). There are also several faults of E-W direction at the west of Agistri which are interrupted by a SW-NE fault.

As observed by the processed satellite image, there might be faults that control the shape of the ridge of the study area (Fig. 6). The major fault of SW-NE direction that lies west of Agistri can easily be identified by the satellite image (F1), as there is a very obvious change of the pixel values and has already been identified by Papanikolaou et al. (1989), using the seismic profiles of the area. There is, also, a lineation of ESE-WNW direction at the north of Metopi island that is possibly due to a normal fault dipping towards the north (F2).

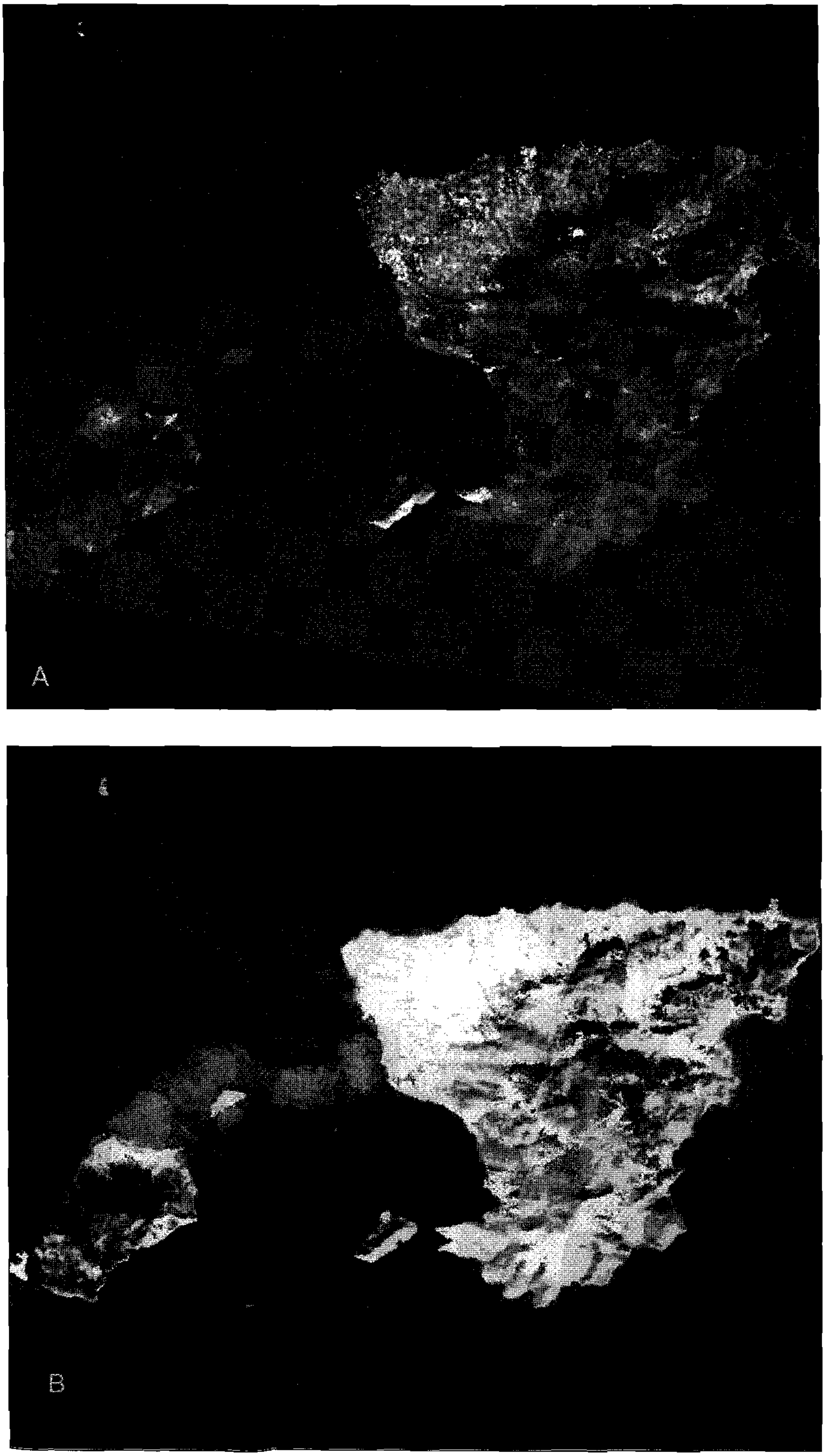

Fig. 4: Landsat 5 TM, band 1, geometrically corrected, subscene of the study area, before (A) and after (B) processing. In the image B is emphasized the well recorded reflectance properties of the bottom, between Agistri and Aegina islands.

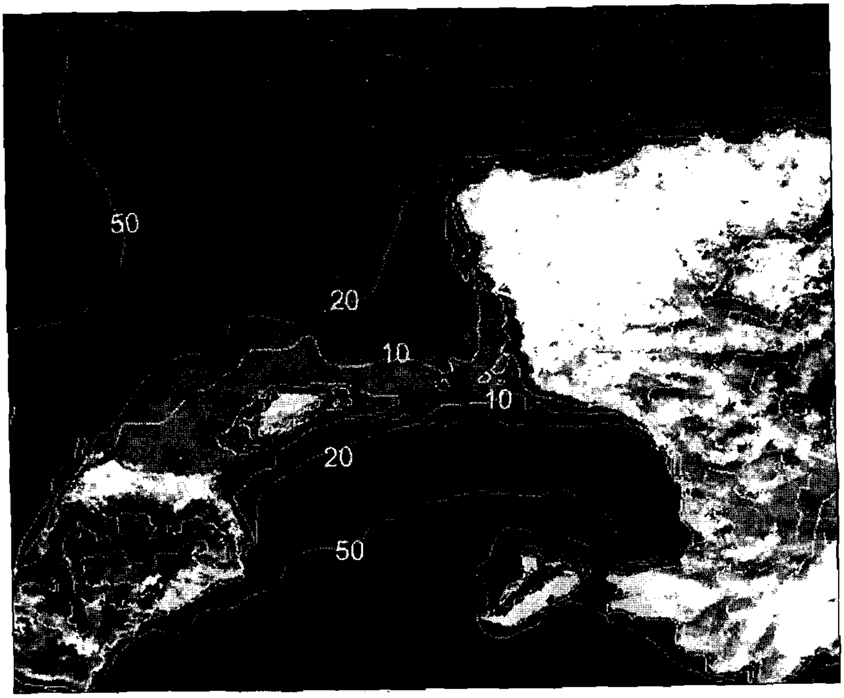

Fig. 5: Digitized contours overlaying the satellite image. There is a high coincidence between the contours and the variation of the pixel values of the bottom area.

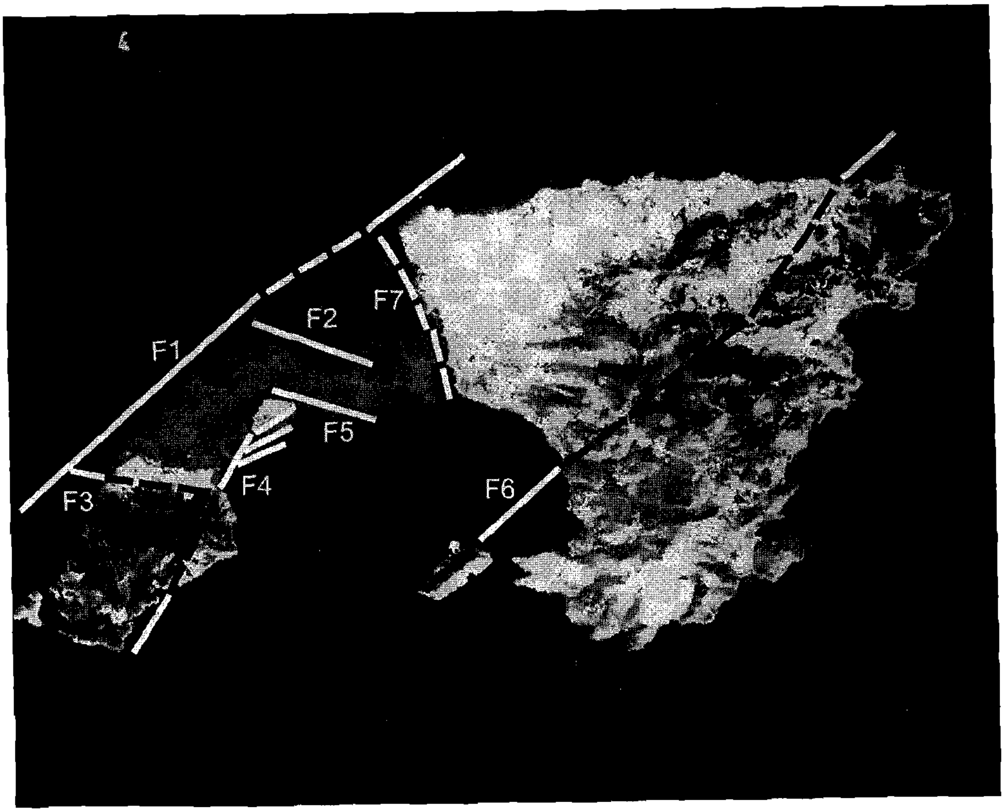

Fig. 6: Interpreted satellite image mainly visually and secondary by computer assistance, with structures (solid line) and possible structures (dashed line), under the water (white) and at the land surface (black).

At the northern coasts of Agistri, there is a lineament of the E-W direction and is possibly due to a normal fault (the downthrow block is the northern) that lies at both of its sides and is covered by sediments (under the water) or by talus scree (at the surface) (F3). At the eastern part of Agistri island, there is a possible fault (F4), that is parallel to F1 (SW-NE), controls the SE coastline of the island and ends at the south coast of Metopi bifurcated into two or three smaller branches, creating submarine stepping terraces, which can easily be observed at the processed image. At the NE of Metopi island a lineation of E-W direction occurs (F5), that is interrupting F4 and delineate the ridge. It appears to be a normal fault dipping towards the south. Another major fault of SW-NE direction (F6), which was, at first, found by seismic profiling (Papanikolaou et al. 1989) in its prolongation in the northeastern submarine area, seems to be continuing on the surface of Aegina recorded as small scarps throughout the sedimentary and volcanic formations and is possibly related to the shape of the rock island Moni at the SW of Aegina. There are also several fractures, of small scale, at the NW of Aegina (F7), which can, easily, be seen by the processed image and seems to be controlling part of the eastern coastline of the island.

6. CONCLUSIONS

It is possible to observe and recognize submarine morphotectonic structures from remotely sensed data, if the depth at the target, does not exceed 15 meters and the quality of the water is fairly good.

The submarine area between the islands of Agistri and Aegina has been affected by recent tectonic events, leading to the formation of particular S-shape morphostructure.

The S-structure of the submarine ridge is possibly created by the combination of the right lateral strike slip motion along the NE-SW fault that lies northwest of Agistri and Aegina (F1) and the left lateral strike slip motion along the fault crossing Aegina with NE-SW direction (F6). The area between the above mentioned faults is characterized by the presence of minor normal faults, which provoked the relative downthrow of the submarine ridge. This subsidence seems to be continuing, nowadays, as the presence of human settlements underwater, indicate.

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