INTEGRATION OF LANDSAT TM DATA AND DEM-DERIVED SPATIAL MODELS TO INVESTIGATE A MACRO-SCALE SHEAR ZONE IN LESVOS ISLAND (GREECE)

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ABSTRACT:

A study concerning the structural setting of the Lesvos island (Greece) is presented, addressed in particular to stress the occurrence of a shear zone, never mentioned in literature, in the southern-eastern side of the island. The research is based on the integrated analysis of satellite images and DEM derived spatial models, with the aim of identifying structural lineaments, whose stastistical investigation would allow to give more insight into the relationships between local brittle and ductile structures and the regional tectonic setting.

1. INTRODUCTION

The integrated analysis of remotely-sensed data and DEM-derived spatial models has allowed to detect and study in details Greek macro and meso-scale geological structures (Migiros el al., 1995). A similar approach has been followed to identify a macro-scale shear zone in Lesvos island (Greece) and to provide an interpretation of it in the framework of the regional structural setting.

This shear zone has never been recognised in either the 1:50,000 scale geologic map or the 1:500,000 scale seismotectonic map (both published by the National Institute of Geological and Mineral Researches, hereafter IGME). Moreover, there is not any published work mentioning this structure, except for a study, concerning a late Cenozoic and Quaternary brittle continental deformation in Western Turkey (Zanchi et al., 1993), where the structure, detected from a Landsat image, is pointed out as lineament without more information. This shear zone is outstanding since it can give more insight into the structural scenario of the SE side of Lesvos island with respect to the tectonic regime of the Aegean sea.

Remote sensing has found large application in geo-structural studies providing a synoptic view of the study area; the basic idea of deriving structural information from the remote sensing data stems from the concept of morphotectonics. Discontinuities are expressed as differences in topography, slope and relief: these morphological differences can be better investigated by integrating remotely sensed data and spatial models derived from a Digital Elevation Model (DEM). The information offered by the DEM and, in general, by the spatial models is important in structural geology (Freda et al., 1990; Onorati et al., 1992) to delineate geomorphologic units (Onorati et al., 1991), ridge and drainage lines (Fairfield and Laymarie, 1991), basins, slope change (Lee, 1994), , and so on. A DEM is a digital representation of terrain relief, describing the geometry of the Earth's surface and is a remarkable component within a GIS system. Being relief a 3D phenomenon, when depicted onto two-dimensional paper or screen surfaces, some problems rise.

The geo-structural setting of Lesvos island has been highlighted by some researchers. Mercier et al. (1989) described the extension tectonic regimes in the Aegean basins during the Cenozoic period. The author suggested that faults kinematics in the northern Aegean area shows three extension tectonic regimes, the tensional directions of which follow WNW-ESE, NE-SW and N-S trends, active respectively during the Upper Miocene, from Pliocene to Lower Pleistocene, from Middle Pleistocene to nowadays. Particularly on the south-western part of the island, a NW-SE striking major fault affects a talus of Mid-Upper Pleistocene age formed by fluvial sands and clays. Small faults affect this talus and their kinematics is in agreement with a N-S trending tension regime. On the western part of Lesvos another NW-SE striking major fault affects Pliocene's marls and clays. The fault planes affecting the Pleostocene's formations demonstrate kinematics which is in agreement only with the N-S trending tension regime.

In 1988 Simeakis described three main fault systems with directions: (i) NNE-SSW (ii) NW-SE and (iii) E-W. The same author suggested a (dextral or sinistral) rotation between the southern areas of the Northern Aegean's trench with respect to those located in the northern part of the trench. Kissel et al. (1988) attained the same conclusion by using paleomagnetic data from the Eubea, Lesvos and Limnos islands. Simeakis (1988) estimated the rotation angle in 6°, being related to the

large scale rotation observed in the Aegean sea. Jacobshagen (1976), on the basis of the results of a statistical analysis, suggested that the fold axis, in the schist formations of south-eastern Lesvos, exhibit a main N-S trend and a southward plunging .

2. LOCATION AND GEOLOGIC SETTING OF THE STUDY AREA

Lesvos is an island located in the Eastern Aegean Sea, very close to the Minor Asia coast, with an extension of 1630.4 sq.km and a 370 km long coast line; it lies between 25° 45' to 26° 45' Easting and 38° 57' to 39° 27' Northing. Its shape is markedly characterised by the presence of two bays, Yera and Kalloni.

The island exhibits an intensive morphological structure and mainly high to medium relief, controlled, in its south-eastern part, by lithology and tectonics. The northern part of the island presents a typical volcanic relief, due to post-alpine volcanic activity. In the eastern part of the island, instead, the geological formations can be summarised as follows (Serelis, 1995):
- *Basement* (Upper Palaeozoic - Middle Triassic) with occurrence of large extension features to the south. The formations, locally up to 1000 m thick, are mainly characterised by schists with intercalation of sandstones and quartzites; some lens of limestones and dolomites are also present.
- *Intermediate clastic formations*. They date back to Triassic and include clastic carbonate and volcano-sedimentary formations. The former is made up by schists, metasandstones, with intercalation of conglomerates; some well layered limestones are also present. The latter are composed mainly by metabasites and sedimentary rocks of crystalline limestones and dolomites.
- *Ophiolites*, distinguished into two groups: the ultrabasic and metamorphic basic ophiolites. The ultrabasic rocks represent the main component and include peridotites and serpentinites often crossed by gabbric dykes. The basic rocks are constituted mainly by amphibolites and amphibolitic schists. Their thickness is about 300 m.
- *Neogene deposits*, represented mainly by pyroclastic materials, exhibiting various lava compositions, and lacustrine deposits.
- *Quaternary deposits,* including fluvial and continental deposits, new and old screes and alluvial deposits in the basins.

As the tectonic scenario is concerned, the SE portion of Lesvos exhibits an isoclinal fold with NE-SW axial trend and a slight plunging towards NE. The recent extension activity and the dynamic processes of the Aegean sea created perpendicular traps along the axis of the fold and dextral rotation of the south-eastern part of the island.

The shear zone, which we are interested in, is located mainly within the so-called Ambeliko-Komis ophiolites and the Neogene pyroclastic deposits, following a NW-SE trend. The landscape of the area, due to lithology and structural setting, is enough various. The middle relief carbonatic areas present very steep slope, an open natural vegetation and absence of soil. The other lithological types (schists, ophiolites) exhibit a moderate slope, a rich soil cover and dense natural vegetation and crops. The plain areas are found close to the coast.

The tectonics of the island is affected by the presence of the Northern Aegean trench, which is the continuation of the great Anatolian fault and extension movements are related to this fault. The above mechanism created in Lesvos N-S (Quaternary), NE-SW(Pliocene) and NW-SE (Upper Miocene) extension directions.

3. DATA SETS AND RELATIVE PROCESSING

To detect the large scale shear zone and the structural lineaments, we have analysed two data sets: a Landsat 5 TM subscene (part of the full scene 181/33, dating 2-8-1989) and a DEM covering the study area.

From the Landsat data we have selected, in particular, the TM 7, 3 and 1 bands, which have been geometrically corrected, taking into account forty GCP's located along the coast line and using to warp the Nearest Neighbour method. For this correction the UTM grid of the 1:100,000 scale topographic map of Lesvos (published by the Greek Military Institute) has been taken into account.

To facilitate the geostructural interpretation, the three selected TM bands have been enhanced by applying linear stretching and, finally, combined onto a FCC image, displaying respectively bands 7,3,1 as Red, Green and Blue (fig.1a).

To create the DEM, the elevation data have been collected by digitising and interpolating along regularly spaced grid the contour lines (equidistance of 40 m) of the already cited topographic map of Lesvos, obtaining a spatial resolution of 60 m/pixel. The DEM has been then processed to calculate spatial models, such as shaded relief, slope and aspect digital images (figs. 1a, 2a, 2b), on the basis of routines provided by GIS packages, such as ILWIS (Migiros et al., 1995), but mostly developed by the authors themselves (Freda et al., 1990; Onorati et al., 1991- 1992). Moreover, these thematic maps have been overlapped, by using ILWIS, to the DEM creating a 3D display.

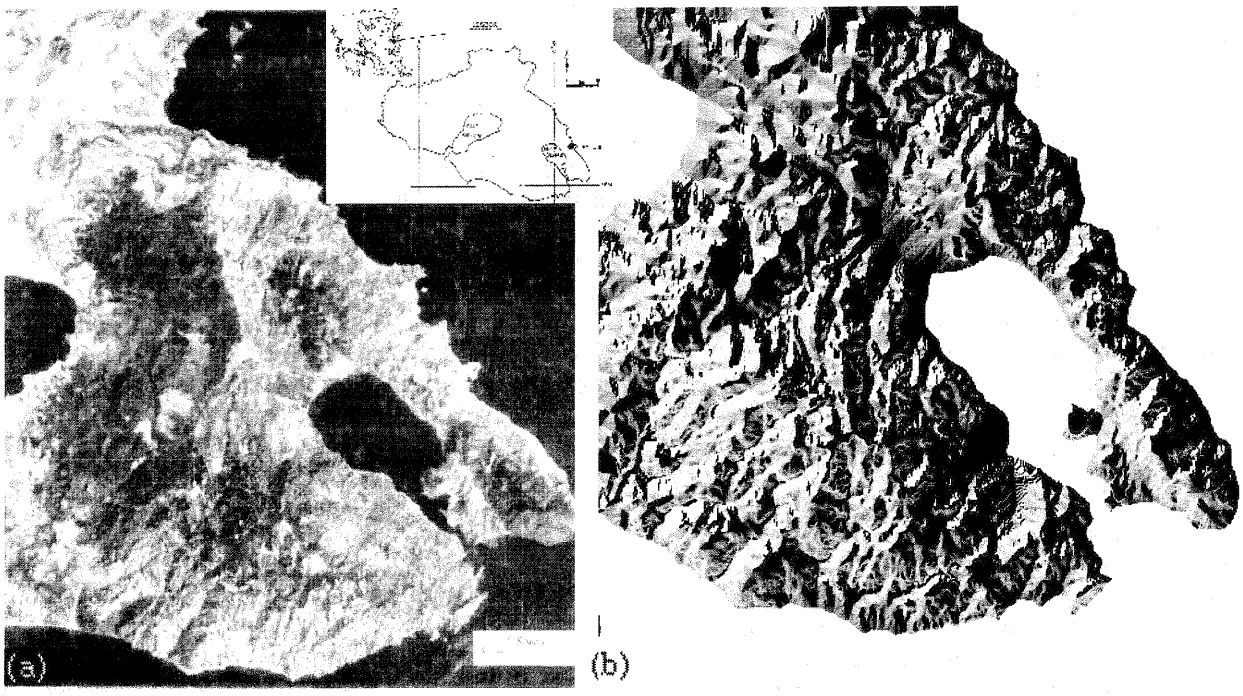

Fig. 1 (a) B/W display of the TM bands 7-3-1 FCC of the Landsat subscene covering the study area;
(b) Combination of slope and aspect maps as derived from the 60 m/pixel DEM of the study area.

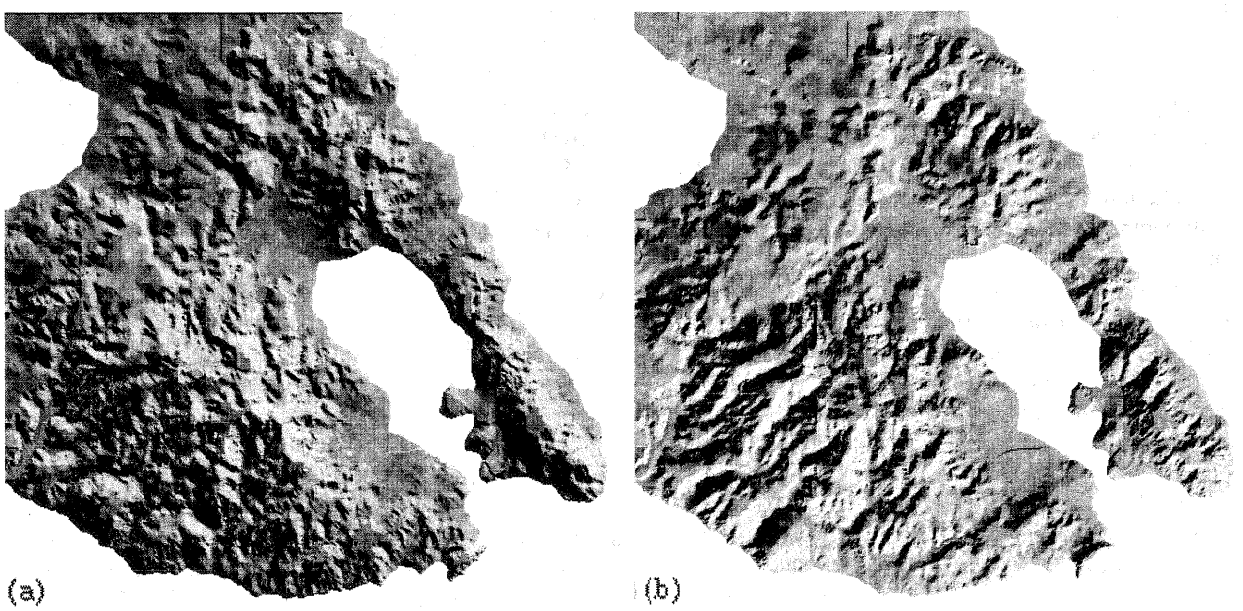

Fig. 2. Spatial Models as derived from the 60 m/pixel DEM of the study area: (a) shaded relief illuminated from NE; (b) shaded relief illuminated from SE.

Both the TM FCC image and the spatial models have been visually interpreted to identify main linear features (figs. 3a, 4a, 4b). On the Landsat image the geological lineaments have been identified by taking into account tone, colour, texture, pattern, and so forth; this has involved some degree of subjectivity and, therefore, the image was interpreted by two authors. The term lineament has been used to imply alignment of different geological features (faults, shear zones, fold axial traces, alignment of streams, and so on). The recognition of the lineaments in the spatial models was based mainly on the topography and morphology. Anyway, in both data

sets the morphological evidence hase been considered more than the tonal differences inside the Landsat picture: this is related to the complex landscape of the SE side of Lesvos. The lineaments have been detected separately from the utilised data sets and have been then statistically treated to derive different groups of azimuth length frequencies bar diagrams.

The main azimuth classes extracted from the TM image (fig. 3b) and the DEM-derived products (fig. 5) have been then compared and interpreted as function of the ongoing geo-structural know-how relative to Lesvos. The results of the combined analysis of satellite data and spatial models were supported also by field geology informations.

4. RESULTS AND DISCUSSION

By interpreting lineament maps (figs 3a, 4a, 4b) and corresponding azitmuth trend statistics (figs. 3b, 5a, 5b), we may stress that in the FCC satellite image the E-W striking lineaments are well detected, mainly in the southern part, but not as so much in the spatial models, where this trend is more evident only in the shaded relief with NE lighting direction. The N-S azimuth trend is also very clear in the satellite image, while in the shaded reliefs, especially in the one illuminated from SE, they do not appear so evident. This may be due to the small size of the N-S trending lineaments, which can be better detected in the FCC image, exhibiting a 30 m/pixlel spatial resolution, with respect to the 60 m/pixel DEM derived spatial models.

Between these digital maps there are differences in structures detecting. In the shaded relief illuminated from SE the NE-SW structural trends can be very well identified, while the conjugate NW-SE trend population is, of course, more evidenced in the shaded relief with NE lighting direction.. In the slope-aspect combination map the circular features are well detected, not in the shaded reliefs: one, detected in the satellite image as well, occurs in the NE part of the southern coast line close to the Yera bay. Some curvilinear feature are also detected in the centre of the TM image in the shear zone area: it probably corresponds to changes in directions of the basins, something like the offsets in the steams case along a fault.

Because of this change in the direction of the basins the shear zone, as morphostructure, is well detected in the slope-aspect combination map and shows up slightly only in the shaded relief illuminated from NE. In the area of the shear zone there is an intensive plastic deformation as revealed by the occurrence of numerous folds. This deformation, outstanding for the study of the shear zone, appears evident only in the FCC TM image, not in the spatial models..

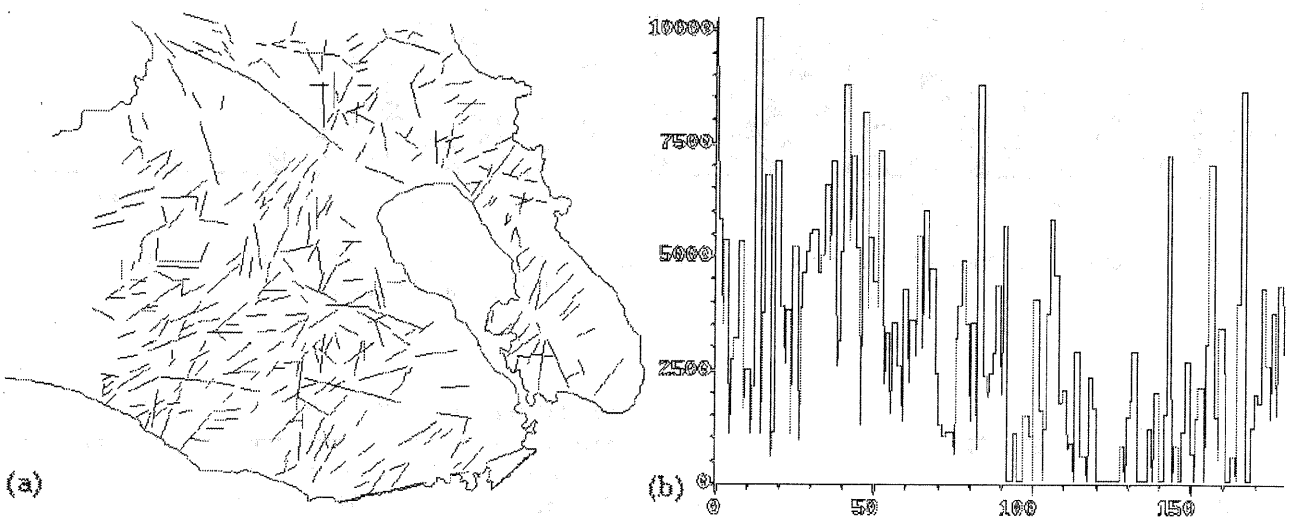

Fig. 3: (a) Sketch map of lineaments derived by photointerpreting the Landsat TM subscene; (b) relative azimuth length frequency bar diagram

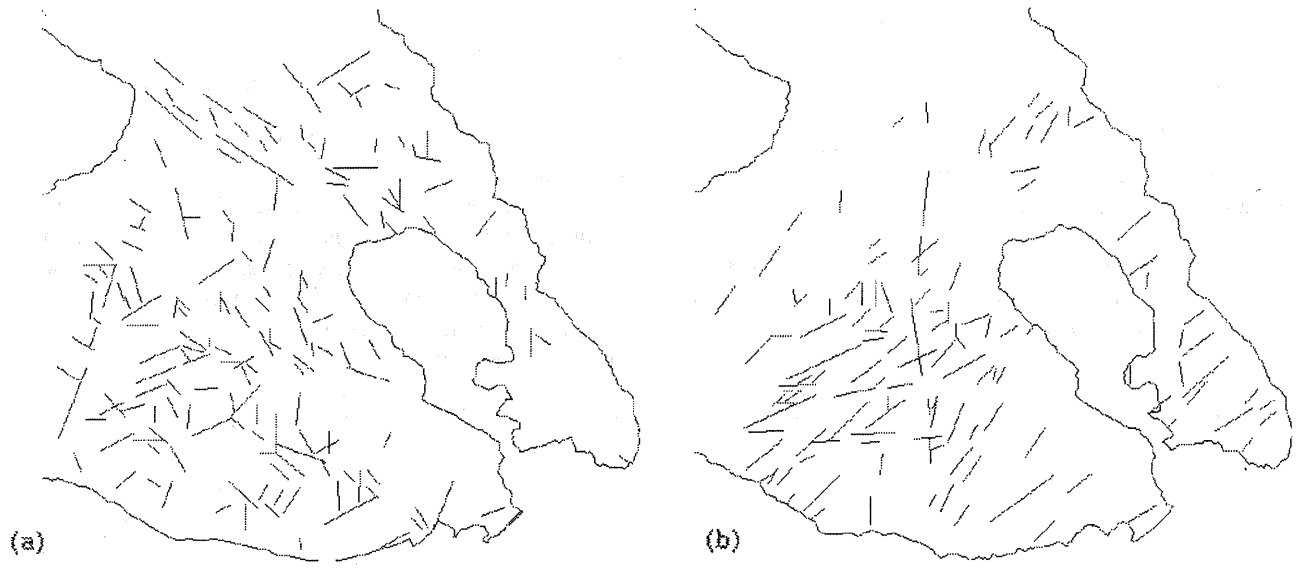

Fig. 4. Sketch map of lineaments derived by photointerpreting (a) shaded relief illuminated from NE (b) shaded relief illuminated from SE

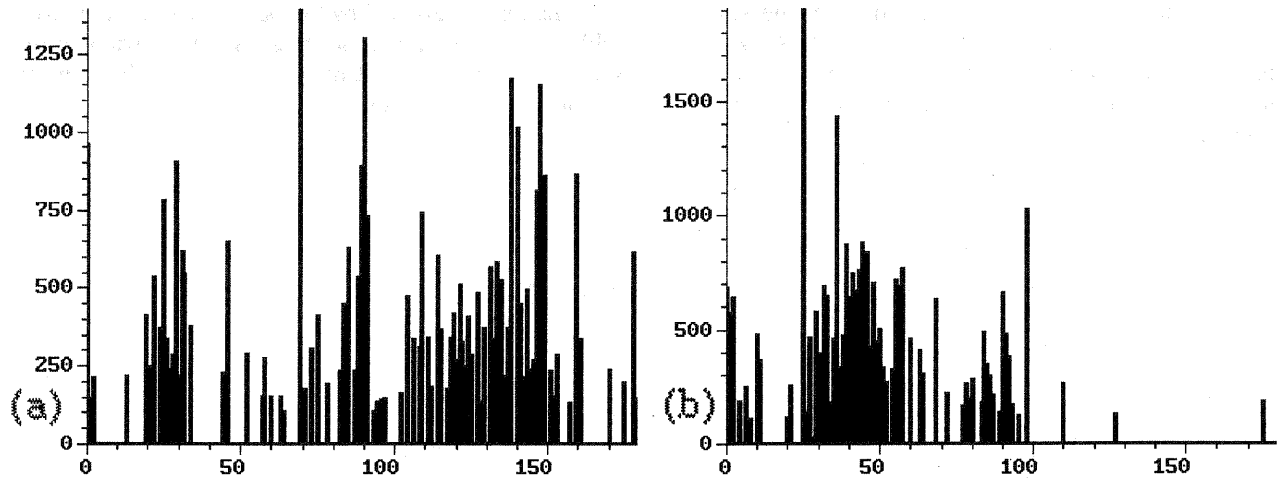

Fig. 5. Length frequency bar diagrams of lineaments derived by photointerpreting (a) the shaded relief illuminated from NE ; (b) the shaded relief illuminated from SE

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