

# **Geomorphological cartography using Remote Sensing and GIS techniques at Milos island**

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## ***Abstract***

This paper presents a GIS-based geomorphological map of Milos island. In order to create this kind of maps, one must employ a wide variety of digital processing techniques, in order to obtain high accuracy and analysis speed. Both aerial photos and satellite images had to be geometrically and radiometrically corrected, in order to eliminate distortions. Using digital image processing techniques, different information layers were developed and imported to the MapInfo GIS. GIS software was used for the comparative spatial and quantitative analysis of all the information layers.

The GIS handled all geomorphological data as separate objects. Thus, every object's attributes and every distance between objects, is easily measurable. Moreover, data modifications and updates are also very quick and easy.

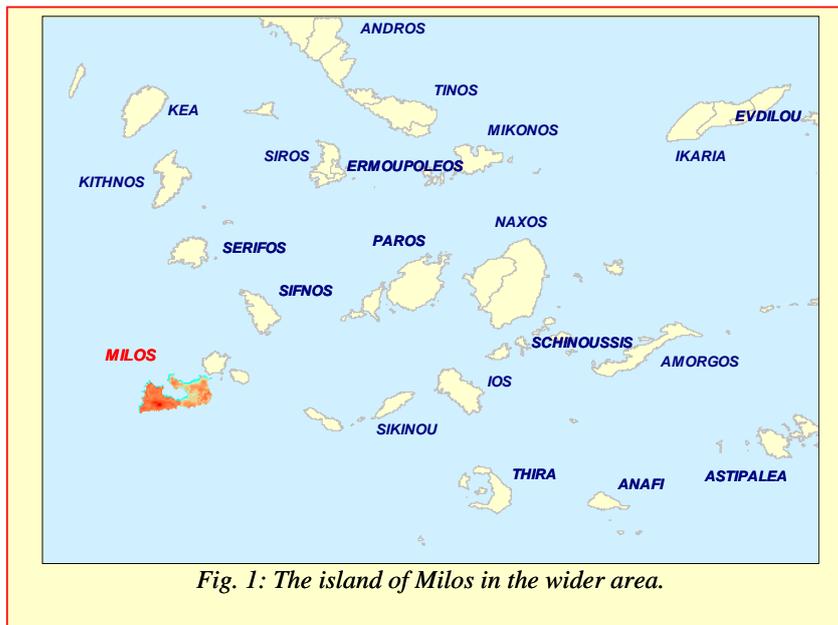
Milos is a volcanic Aegean-sea island. Over the last decades, significant geomorphological changes have taken place, because of rapid increment of tourism. The rapid, and of a large scale, geomorphological changes that have already taken place and will continue in the future, were the reason why Milos island was selected among others to be studied from a geomorphological point of view. This paper's aim is to record geomorphological features of Milos island in order to be compared with data that will be gathered in some years at the second stage of this study, in order to present geomorphological changes due to human activity impacts.

## ***Introduction***

Milos is the western island of the Cyclades complex (Fig. 1), with a total area of 159Km<sup>2</sup>. The island's morphology may be described as low and hilly, with the eastern part being more flat compared to the western, its highest peak being Profitis Ilias (751Km).

As far as the lithological characteristics of Milos are concerned, the oldest rock formations are metamorphic, forming the crystalline basement, which appears at a very thin and limited area (0.6675km<sup>2</sup>), mostly at the southeast coastline of the island (Fig. 2 a,b,c). This basement is folded and intensively eroded.

The transgressed Miocene–Pliocene sea sediments are lying over the crystalline basement, with a total extent of 4.044km<sup>2</sup>, as estimated through GIS techniques. This series is not continuous throughout Milos; it begins with reddish conglomerates and ends up with well-bedded limestones, which at places turn to sandstones (Fytikas, M.,



1977). The most important occurrences are at the south and southwest part of the island. The Neogene deposits are followed by volcanic activity products (Fig.3), which had started at the Upper Pliocene and terminated at the upper Quaternary (Fytikas, M., 1977, Fytikas, M., et al, 1984) and may be separated into two categories; volcanic rocks and lavas that both cover the largest part of the island (123.92Km<sup>2</sup>). The stratigraphic sequence closes with quite a large occurrence (30.38Km<sup>2</sup>) of recent alluvial deposits in discordance to the previously described volcanic products.

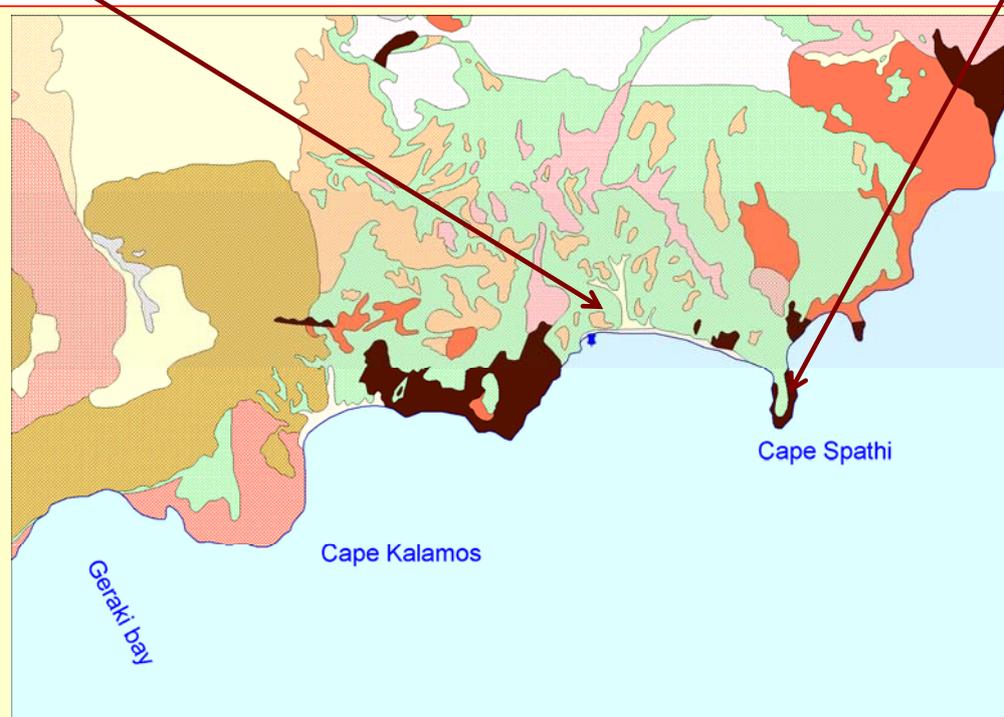
Based on Milos lithological characteristics, we may divide the whole island into the following main geomorphological units:

- The unit characterised by low hills, with medium slopes, where pyroclastic materials and volcanic rocks dominate. These volcanic activity products are prone to precipitation weathering.
- The unit with high hills and high slope values, that consists of volcanic domes with lava flows. The mechanical characteristics of the volcanic materials, lead to the development of very steep slopes, as one may see at the “Castle of Plaka” dome.
- The unit with formations that are likely to be phreatic explosion craters.
- The unit that is mainly characterised by very low slope values, that have been developed on the green lahar formation. The area of this unit, is often interrupted by valleys with increased downcutting, due to intense seasonal rainfall.
- Finally, the unit of alluvial plains.

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*Fig.2a : At this photo we may see the green lahar deposits, the grey-green metamorphic rocks (at the right part of the picture in Spathi cape), the lavas under lahar in the left of the image and the redish, thin volcanic sediment formations, overlaying the lahar formation.*



*Fig.2b: Part of Milos geological map, showing the wider area of Spathi cape, shown in Fig.2a.*

### Geological formations

- Alluvial deposits
- Coastal deposits
- Fans and scree
- Old torrential-fluvial deposits
- Porous tuffs
- Phryiplaka lahar
- Phylithic lava domes & mainly successive lava flows
- Thin layers of reworked pyroclastic material of Phryiplaka volcano
- Phryiplaka and Trachilas pyroclastic cones
- Green lahar
- Various lahar
- Recent tuffitic layers
- Layered pyroclastic deposits (recent tuffs)
- Andesitic and dacitic lava domes and flows
- Pyroclastic flows (nuee ardente or glowing avalanches)
- Ignimbrites of Agathia (NW Milos)
- Andesitic, dacitic to rhyodacitic lava
- Boudhia pyroclastic formation
- Rhyolitic-rhyodacitic lava
- Strongly hydrothermally altered lava
- SW Milos ignimbrites
- Old tuffites
- Old tuffs
- Pumice flow deposits
- Strongly altered tuffs
- Strongly altered volcanic formations
- Transgressive conglomerates and limestones
- Crystalline basement

( GPS point

*Fig2c.: Milos geological map's legend. A part of the geological map is shown at Fig 2b.*



*Fig.3: Pyroclastic deposits at Sarakiniko area. The deposits have many small fractures with a general direction of East-West.*

## Methodology

For the recognition, imprinting and electronically recording of the geomorphological data of Milos island, the aerial photos of Hellenic Military Geographical Service (HMGS), scaled 1:30.000 and taken in 1988, were used as primary material; while the topographical (HMGS 1975 for Milos sheet and 1976 for Kimolos sheet) and geological (Institute of Geology and Mineral Exploration, 1953) maps were used as a base.

GIS MapInfo Professional software was used as a core for this study, where primary information were inserted and then processed a) for the production of secondary information layers, and b) finally the composition and creation of the geomorphological map of the island.

Initially, information from the topographical maps was input into GIS MapInfo (such as inland and submarine relief, drainage system, road network and built up areas), whereas geological formations and faults from geological maps, in separate information layers. All the above data composed the digital database for the recording and process of the geomorphological data derived from fieldwork and aerial photos.

For the digital processing, the production of the ortho-photomosaic and the stereoscopic photointerpretation, the aerial photos were scanned at 1200x1200dpi resolution. The radiometrical and geometrical corrections of the photos followed, through Image Station software, with a purpose of obliterating distortions and smoothing brightness and contrast differences, so that the creation of a photomosaic and the stereoscopic observation through the computer screen would be possible (Evelpidou, N., 2001). Figure 4 demonstrates the procedure followed during this study.

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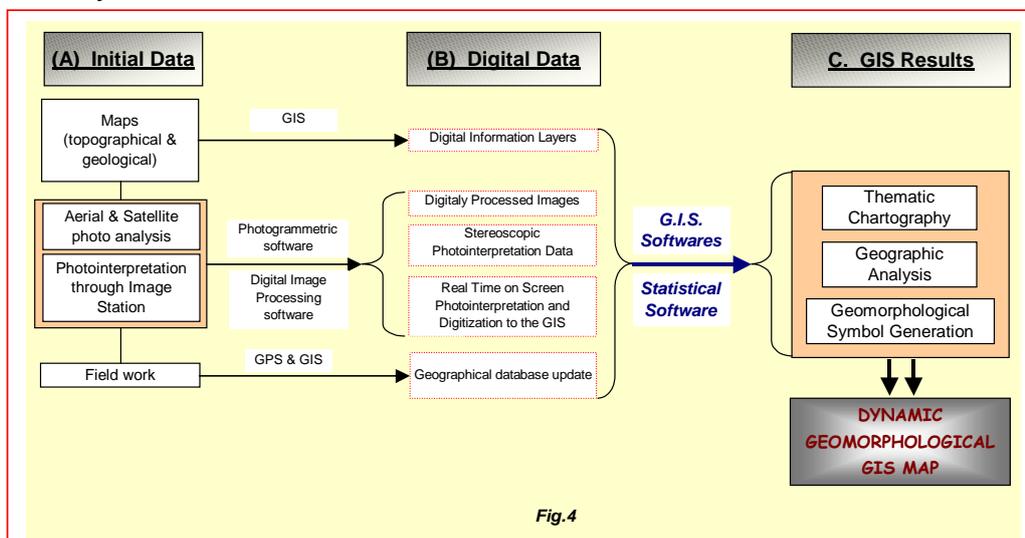
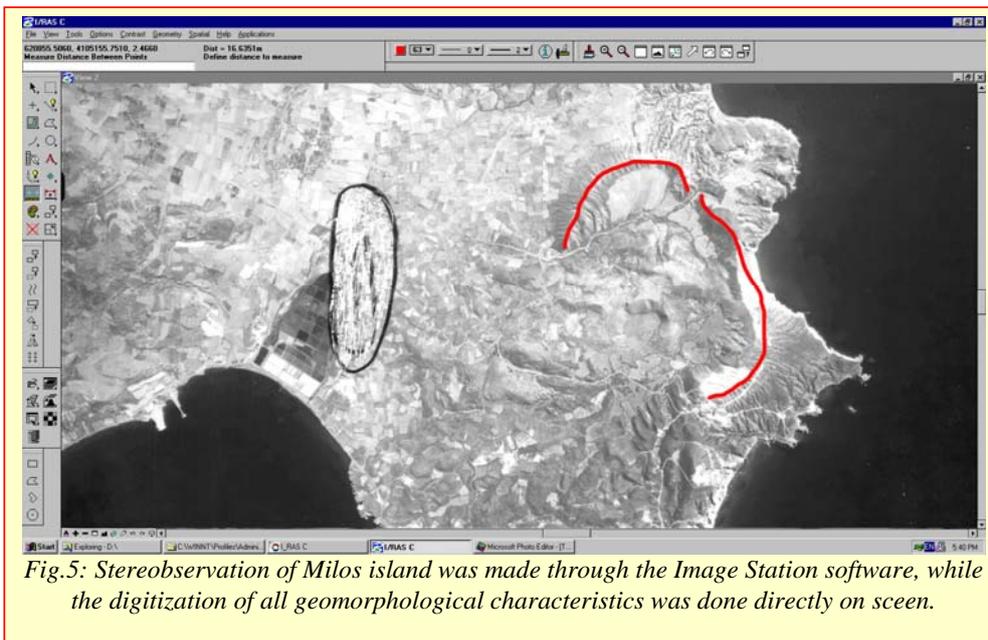


Fig.4

The use of digital elevation model (DEM) allowed the production of the digital image anaglyf of the photomosaic. In order to carry out the stereo-observation through the computer screen, with potential of simultaneous digitization of geologic formations, special software (Image Station) was used. This undertakes a high

frequency of both aerial photos of the stereoscopic pair, concerting through infra-red sign the special glasses of liquid crystal which the user has to wear. The co-ordination consists of the simultaneous observation of the right image through the right lens, and the left image through the left lens by the user, thus making stereo-observation possible.

The digitization of geomorphological formations, during stereo-observation through the computer screen, was made directly through the connection of the photogrammetric system to the Geographical Informational System (Fig. 5). At the same time, the insertion of data was automatically creating new blank recordings into the database that was connected to the GIS through ODBC drivers. This methodology speeds up the transference of data from the image into the GIS diminishing at the same time the accuracy problems resulting from the different age and scale of the aerial photos and maps.



*Fig.5: Stereobservation of Milos island was made through the Image Station software, while the digitization of all geomorphological characteristics was done directly on scen.*

The formations' that were mapped through photo-interpretation were retrieved through extensive fieldwork. For the preservation of the accuracy of the geological formations position during fieldwork, the Global Positioning System (GPS) was used, the data of which were directly connected to the MapInfo database. During fieldwork the position of some geologic formations that had been recorded through stereo-observation were verified therefore the identification of the characteristics was possible.

Finally, appropriate symbol libraries were created into the GIS, to symbolize several geologic formations (such as erosional remnants), with a purpose of achieving the best representation of all the data on the geomorphological map of Milos. The use of GIS, besides providing the possibility for the production of secondary information layers and the best representation of the geomorphological map, also allows future quantitative and spatial use of the geomorphological data, individually or in

combination with other data, regarding their geography as well as the database that corresponds to each one of them.

### ***Conclusions***

Milos geomorphology is quite complicated, with many significant differences compared to the rest of the Cyclades complex islands, mainly due to the large occurrences of volcanic activity products, that form a completely different lithological structure. Another factor that led to those geomorphological differences, is the vast human activity impact at the whole area, that rapidly alters the morphology from one year to the other.

During data input and analysis, the remote sensing and photogrammetric techniques, combined to the GIS capabilities, enabled us to develop a large database of geomorphological features, retaining the best accuracy and flexibility. Even through fieldwork, GPS equipment was ensuring high accuracy positioning and GIS data entry. The primary data were collected through the photointerpretation of Milos aerial photos, with on screen three-dimensional observation. The techniques, employed to this study, may be used to any other study of geomorphological features.

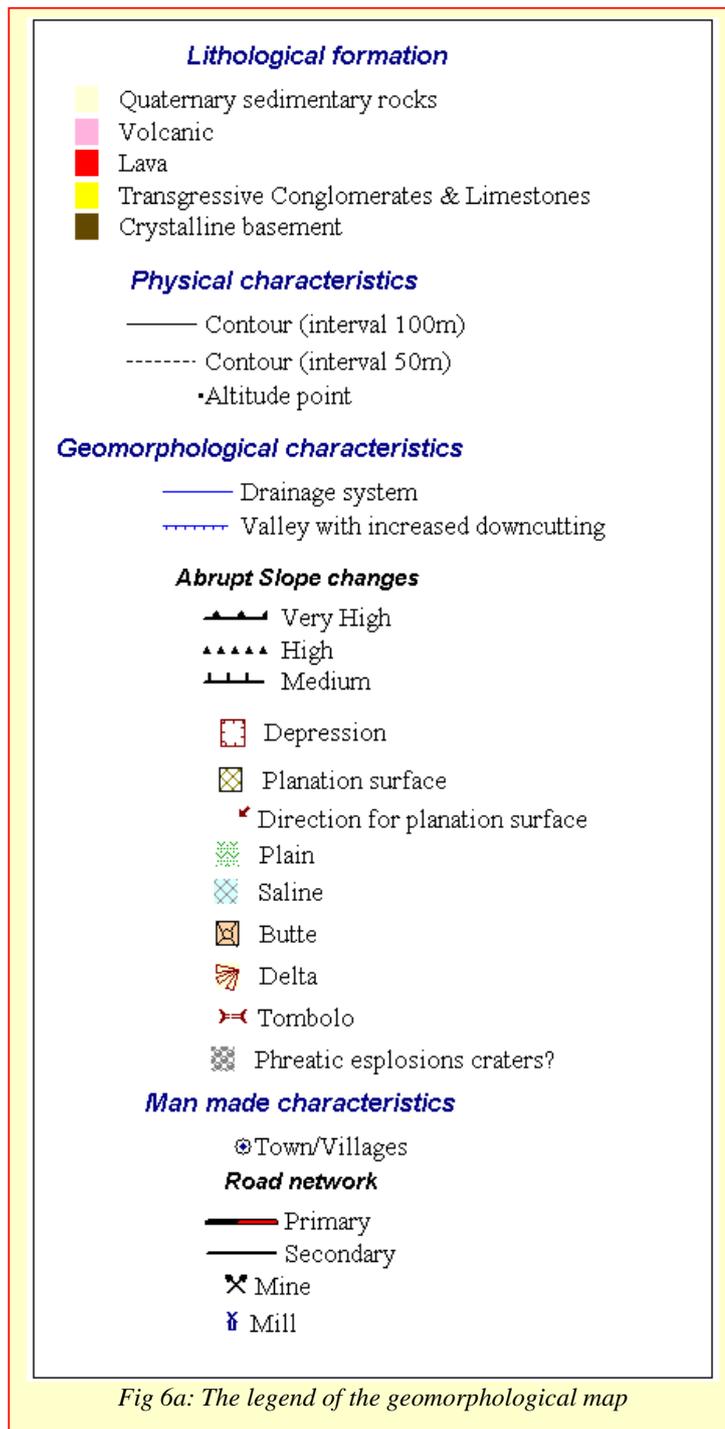
This study resulted to the creation of a detailed geomorphological map of 1:30.000 scale (Fig.6a,b) and the analysis of Milos most important geomorphological features, as well. Both tasks were achieved through the combination of different digital technology means, such as digital image analysis, GIS techniques and statistical analysis algorithms. Many of the primary input data and the results, were integrated and cross-tested through extensive field work.

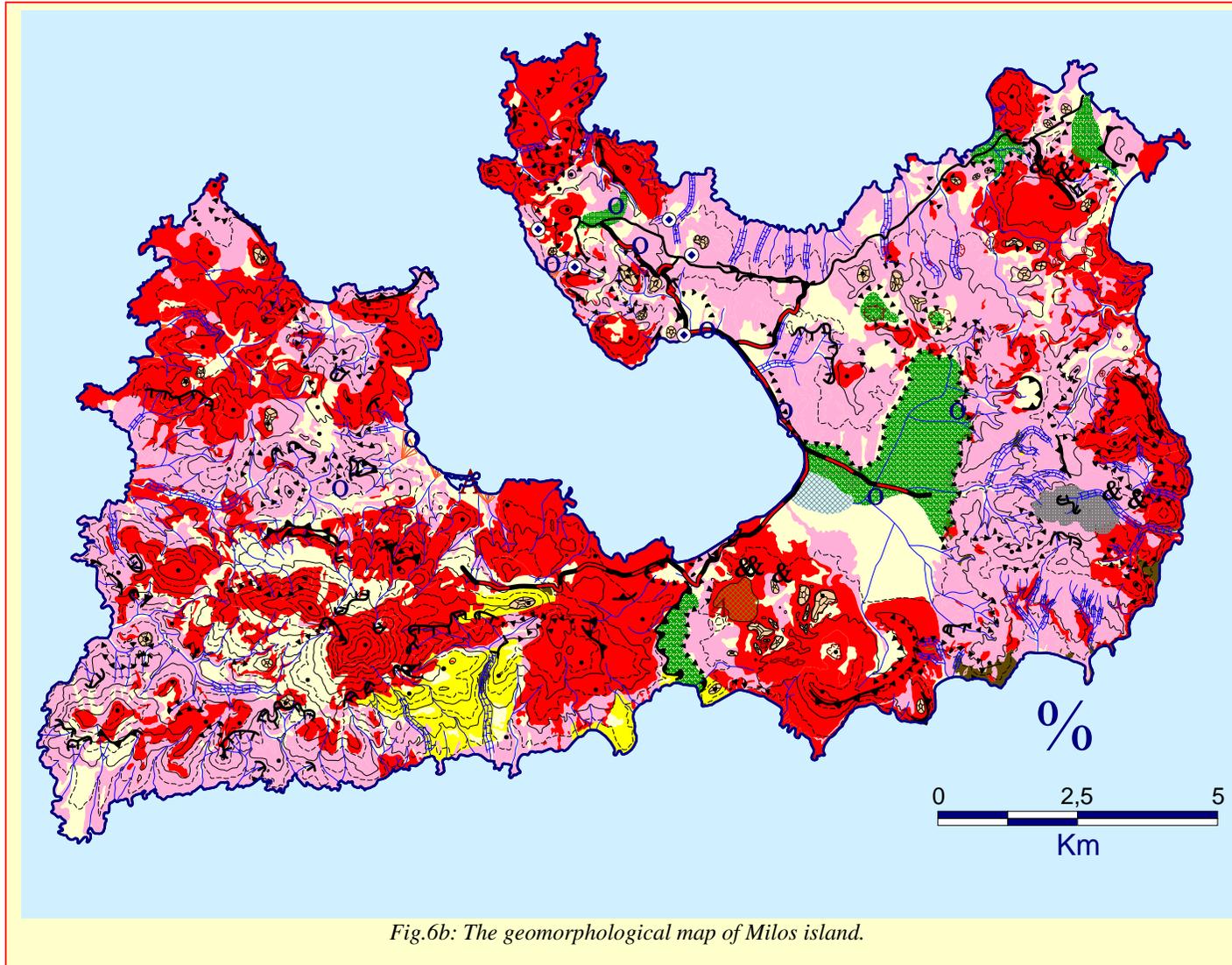
Apart from the above, the developed geomorphological GIS database is a preliminary work that will be used for further geographical and quantitative analysis, mainly on the basis of recording and evaluating geomorphological changes resulting from the significant human impact.

### ***References***

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*Fig.6b: The geomorphological map of Milos island.*