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USING REMOTE SENSING MULTISPECTRAL DATA AND GIS TECHNIQUES FOR THE GEOLOGICAL MAPPING OF HALKI ISLAND

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Abstract

In this paper we present the combined use of remote sensing and GIS techniques for the geological mapping of Halki Island at 1/50.000 scale. The geological formations, geotectonic units and tectonic structures were recognized in situ and mapped. Interpretation of multispectral satellite images (Landsat TM & ETM and Terra ASTER) has been carried out in order to detect the linear or not structures of the study area. Different band ratio was also used in order to distinguish and map the limits of the different geotectonic units. The in situ mapping was enhanced with data derived from the digital processing of the satellite data. All the analogical and digital data were imported in a geodatabase specially designed for geological data. After the necessary topological control and corrections, the data were unified and processed in order to create the final map layout at 1/50.000 scale.
Key words: *Halki, 1/50.000, geological map.*

Περίληψη

Στην εργασία αυτή παρουσιάζεται ο Γεωλογικός Χάρτης κλίμακας 1/50.000 Φύλλο "Νήσος Χάλκη" που εκδόθηκε από το ΙΓΜΕ. Για τη δημιουργία του χάρτη έγινε συνδυαστική χρήση δορυφορικών πολυφασματικών δεδομένων (Landsat TM & ETM and Terra ASTER), και χαρτογράφησης στο πεδίο με χρήση DGPS. Όλα τα δεδομένα εισήχθησαν στην ειδικά σχεδιασμένη γεωβάση του ΙΓΜΕ. Μετά τους απαραίτητους τοπολογικούς ελέγχους και τις αναγκαίες διορθώσεις τα δεδομένα ενοποιήθηκαν και έγινε η επεξεργασία τους με σκοπό τη δημιουργία του τελικού χάρτη.
Λέξεις κλειδιά: *Χάλκη, Γεωλογικός Χάρτης, 1/50.000.*

1. Introduction

The Institute of Geology and Mineral Exploration of Greece is the state's advisor on geoscientific issues. One of its main activities, which established the role of IGME in the field of the systematic research, study and mapping of the geological environment, at national and international level, is the geological mapping of Greece at various scales. The basic geological cartographic scale of

IGME is the 1:50.000. The whole country is covered by 326 map sheets, most of them accomplished during the last six decades by Greek and foreign geologists.

In many regions of Greece there is no continuity between adjacent geological maps (e.x. heterogeneity - discontinuity of geological features such as formations, tectonic lines, geological units). Furthermore a very few map sheets have not been published.

In order to heal these heterogeneities IGME has integrated a project involving the updating or publishing of fifty geological map sheets using GIS and Remote Sensing techniques, one of which was the geological map sheet of Halki. The project was founded in the framework of CSF 2000 – 2006 (Community Support Framework 2000-2006, Operational Program Competitiveness, Priority axis 7: Energy and Sustainable Development, Measure 7.3: Exploitation of natural recourses and support in meeting environmental commitments, Action 7.3.1) under the auspice of a project titled "Collection, Codification and documentation of geothematic information for urban and suburban areas in Greece - pilot applications".

In this paper we present the combined use of remote sensing and GIS techniques for the geological mapping of Halki Island at 1/50.000 scale. The geological formations, geotectonic units and tectonic structures were recognized in situ and mapped. Interpretation of multispectral satellite images (Landsat 7 ETM and Terra ASTER) has been carried out in order to detect the linear or not structures of the study area. Different band ratio was also used in order to distinguish and map the limits of the different geotectonic units. The in situ mapping was enhanced with data derived from the digital processing of the satellite data. All the analogical and digital data were imported in a geodatabase specially designed for geological data. After the necessary topological control and corrections, the data were unified and processed in order to create the final map layout at 1/50.000 scale.

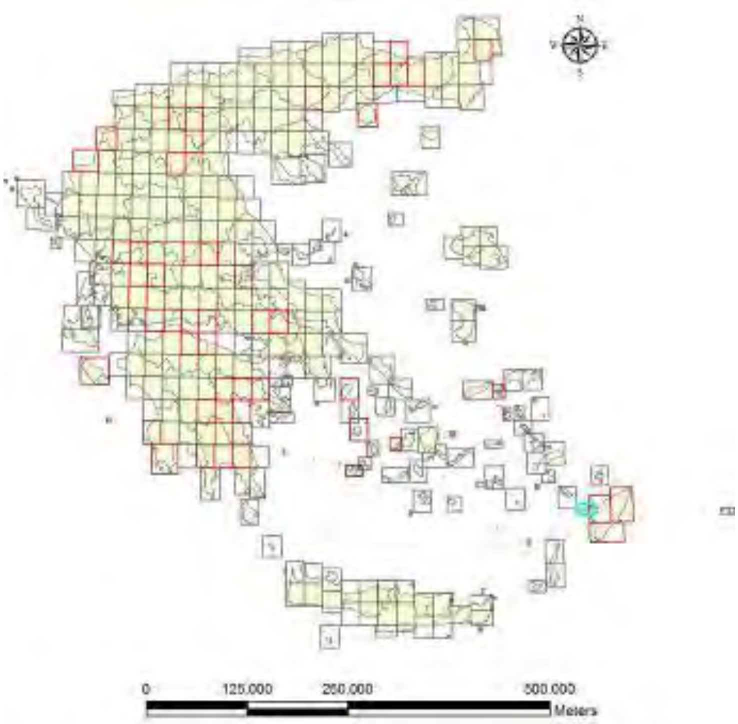

Figure 1 - The Greek territory is covered by 325 geological maps at 1/50.000 scale. With red color some of the geological maps that have been updated. With blue color the new Xalki Island map sheet.

2. Remote Sensing Data and Processing

2.1. Remote Sensing Data

Landsat imagery was successfully used throughout the years for geological structure recognition due to its synoptic view over large areas, enabling the detection of regional geological features. In particular, lineament analysis of remotely sensed data, either by visual or automatic interpretation, is a valuable source of information for studying the structural setting. Although, Landsat satellite TM data has proved useful for regional geological studies (Abrams et al., 1988), its coarse spectral resolution provoked difficulties to a detailed mapping of geological composition. This obstacle was overpassed with the launch of Landsat 7 and Terra satellites. Both ASTER instrument and ETM with a spatial resolution (for the Vnir and panchromatic band respectively) gave a new impulse to the use of satellite data for geological mapping .

Different algorithm has been applied in geological research, especially to detect geological lineaments such as fault, joints, dykes, and shear zones (Cross and Wadge, 1988). Other researchers (Wang and Howarth, 1990) used Hough transform for automated lineament analysis using parts of Landsat TM images. The synergistic use of optical and radar data for the detection of active faults was proposed (Parcharidis et al., 2001). Digital Elevation Models were also used for the detection of linear features and the extraction of the topographic structure (Jenson and Domingue, 1988).

Different RGB combinations and band ratios of ASTER data were used for geological mapping in different geological environments (Kavak, 2005; Nair and Mathew, 2012; Deller 2006; Nikolakopoulos et al., 2009; Oikonomidis et al., 2009). Visible, near-infrared and short wave infrared reflectance data (9 ASTER bands) have been processed and interpreted in framework of a mapping project concerning the western margin of the Kalahari desert (Gomez et al., 2005.). The same authors have also used Principal Component Analysis as a preliminary processing step before the classification of the ASTER data. In another study Gad Kusky, 2007) used different ASTER band ratios for lithological mapping in Egypt. Different combinations of ASTER band ratios were also used for lithological mapping in California (Rowan and Mars 2002). Principal Component Analysis method was applied in ASTER data in combination of NDVI and different False Colour Composite images for lineaments mapping in Crete (Papadaki et al., 2011).

In this study two ASTER, a Landsat TM and a Landsat ETM images were processed in order to detect different geological formations. In order to extract the maximum spectral info of each band the Principal Component Analysis, the Independent Component Analysis, the Tasseled cap and different combinations of band ratios were used. The results are presented in the next paragraphs.

2.2. Principal Component Analysis

Principal Components Analysis (PCA) was originally used as a method of data compression. It allows redundant data to be compacted into fewer bands--that is, the dimensionality of the data is reduced. The bands of PCA data are non correlated and independent, and are often more interpretable than the source data.

PCA was applied in ASTER SWIR data (Figure 2) and also in Landsat TM (Figure 3) and ETM (Figure 4) data. The upper formation with purple colour in Figure 2 and cyan to purple colour in Figure 3 corresponds to the limestone-dolomitic limestone of the Gavrovo Tripolis geotectonic zone. The lower formation presented with red colour in Figure 2 or with yellow colour in Figure 3 corresponds to the Lower Jurassic-Lower Cretaceous Limestones of the Gavrovo Tripolis geotectonic zone. Two small appearances of alluvial deposits (blue color in Figure 3 or purple colour in Figure 4) are easily detected inside the limestone formation in the east part of Halki Island while a more extensive appearance of alluvial is presented in the south part of the Island. Next to the alluvial deposits the Flysch of the Ionian zone can be distinguish with purple colour in Figure 3 or cyan to green colour in Figure 4.

Figure 2 - RGB combination of the ASTER SWIR principal components 142. Four different geological formations can be recognized.

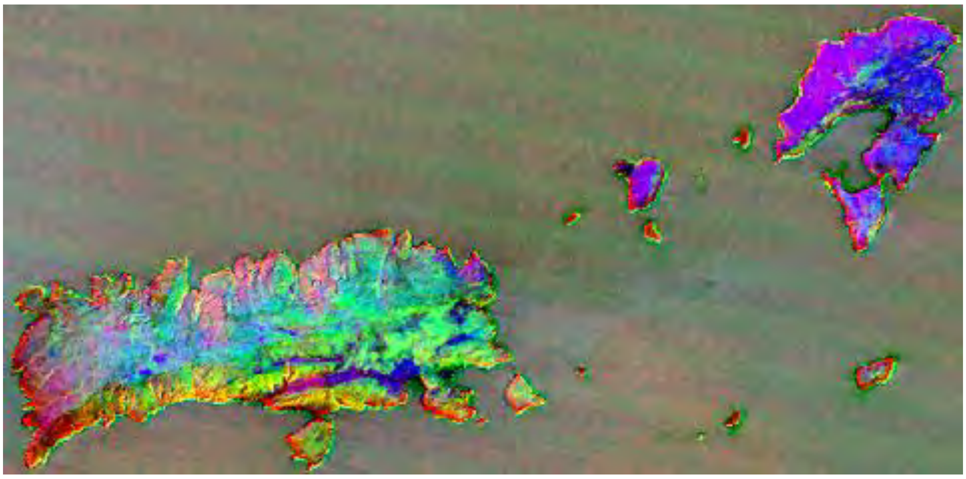

Figure 3 - RGB combination of the Landsat TM principal components 432. Four different geological formations can be recognized.

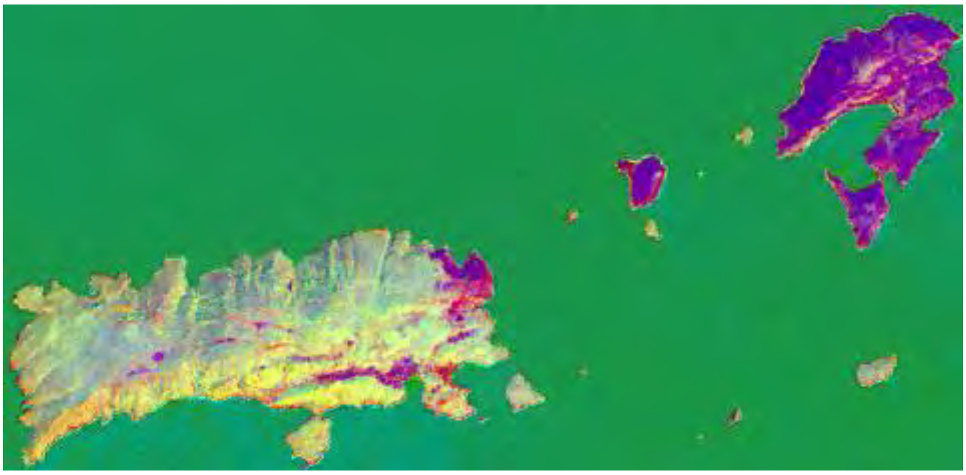

Figure 4 - RGB combination of the Landsat ETM principal components 142. Four different geological formations can be recognized.

2.3. Independent Component Analysis

Independent Components Analysis is a feature extraction technique which aims to decorrelate the spectral bands in order to recover the original features in the image. It performs a linear transformation of the spectral bands such that the resulting components are decorrelated. Each component will contain information corresponding to a specific feature in the original image.

Independent Components Analysis was applied in ASTER data (Figure 5) and also in Landsat TM and ETM data (Figure 6). The upper formation with green colour in Figure 5 and brown colour in Figure 6 corresponds to the limestone-dolomitic limestone of the Gavrovo Tripolis geotectonic zone. Two small appearances of alluvial deposits (pink colour) are easily detected inside the limestone formation in the east part of Halki Island while a more extensive appearance of alluvial is presented in the south part of the Island.

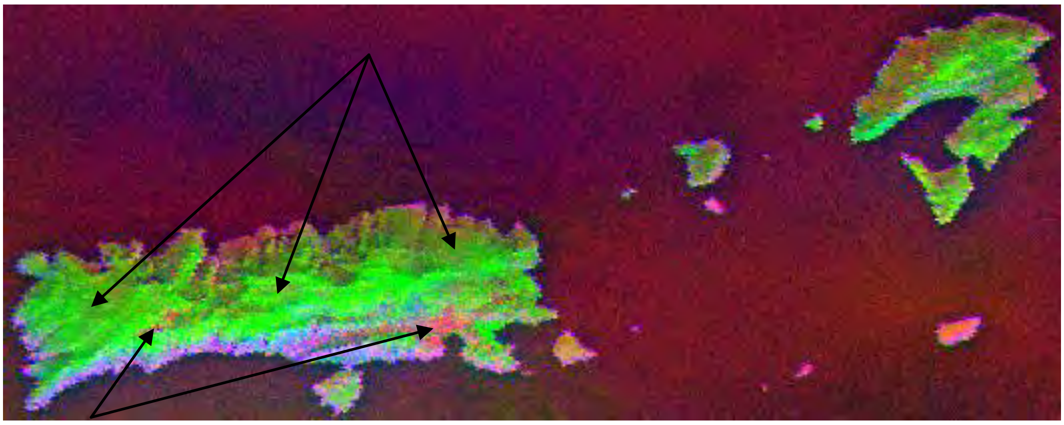

Figure 5 - RGB combination of the ASTER SWIR independent components 621. Four different geological formations can be recognized.

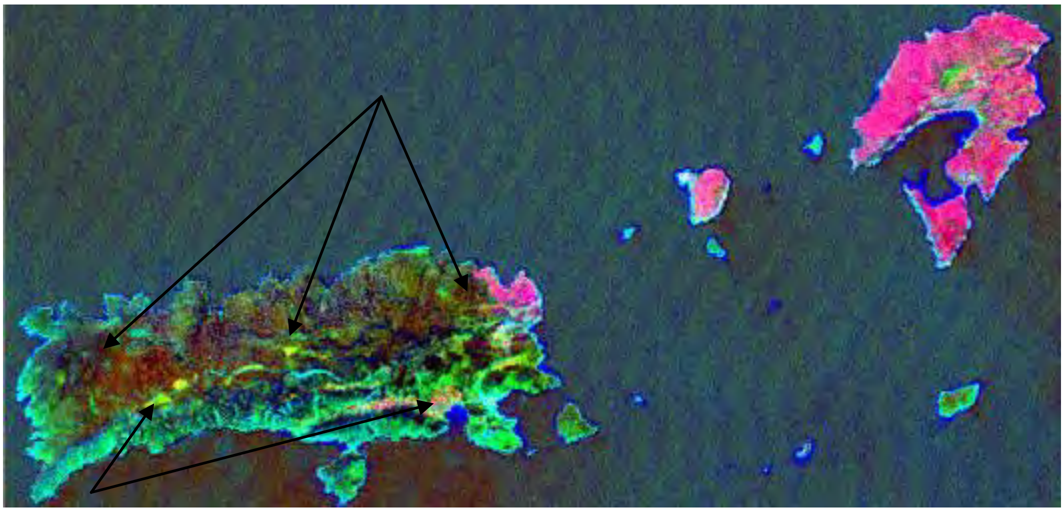

Figure 6 - RGB combination of the Landsat ETM independent components 431. Four different geological formations can be recognized.

2.4. Band Ratios

Band ratio images designed to display the spectral contrast of specific absorption features have been used extensively in geologic remote sensing (Rowan, 2003). Relative absorption depth

(RBD) images are an especially useful three-point ratio formulation for displaying Al-O-H, Mg-O-H and CaCO3 absorption intensities prior to conducting more detailed, time-consuming spectral analysis (Crowley et al., 1989). For each absorption feature, the numerator is the sum of the bands representing the shoulders (bands 1 and 2), and the denominator is the band located nearest the absorption feature minimum (band 3); removal of continuum increases the intensity of the absorption feature: RBD = (band 1 + band 2) / band 3 (according to Crowley et al., 1989)

Several different band ratio images have been created. The [(band 7 + band 9)/band 8] image which highlights the CaCO3 and Mg-O-H absorption feature at 2237.5 nm is presented in Figure 7. The specific band ratio image corresponds well with the limestone dolomite-limestone distribution in the north part of Halki Island. Another absorption RBD image [(band 6 + band 8)/band 7,)] exhibits correspondence with the dolomite distribution in the north part of Halki Island (Figure 8).

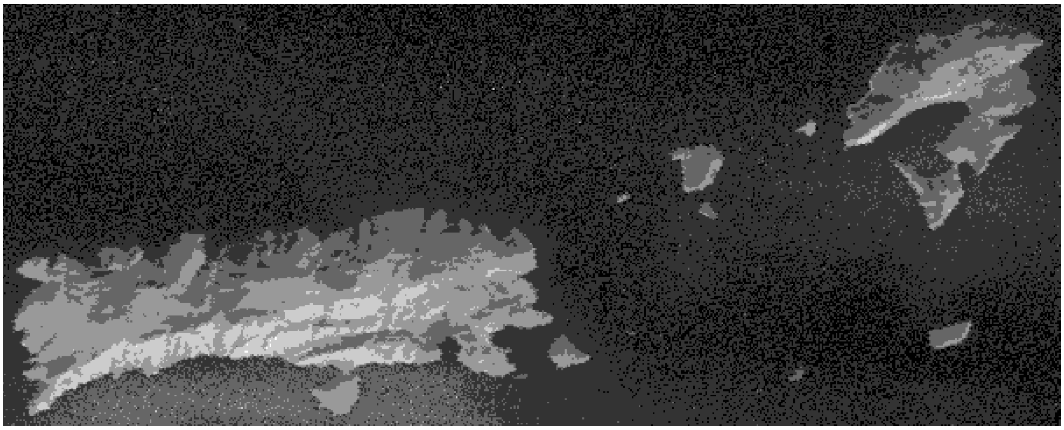

Figure 7 - Band ratio of the ASTER SWIR image. The formula was (band7+band9)/band8. The specific band ratio image corresponds well with the limestone dolomite-limestone distribution in the north part of Halki Island.

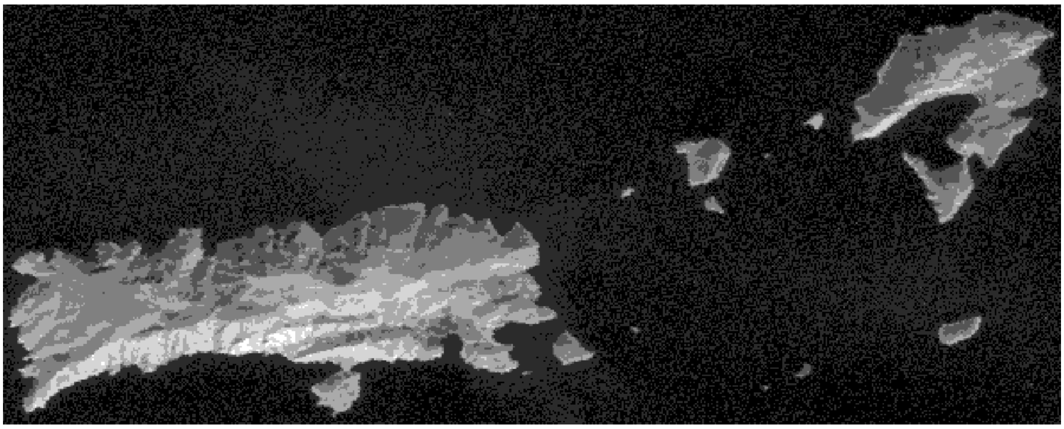

Figure 8 - Band ratio of the ASTER SWIR image. The formula was (band6+band8)/band7. The specific band ratio image corresponds well with the limestone dolomite-limestone distribution in the north part of Halki Island.

2.5. Tasseled Cap

Tasseled Cap transformation offers a way to optimize data viewing for vegetation studies. For example, a geologist and a botanist are interested in different absorption features. They would want to view different data structures and therefore, different data structure axes. Both would benefit from viewing the data in a way that would maximize visibility of the data structure of interest. The tasseled cap image og the ETM data is presented in Figure 8. The difference in colour between the dolomitic-limestone and the limestone with silex is obvious.

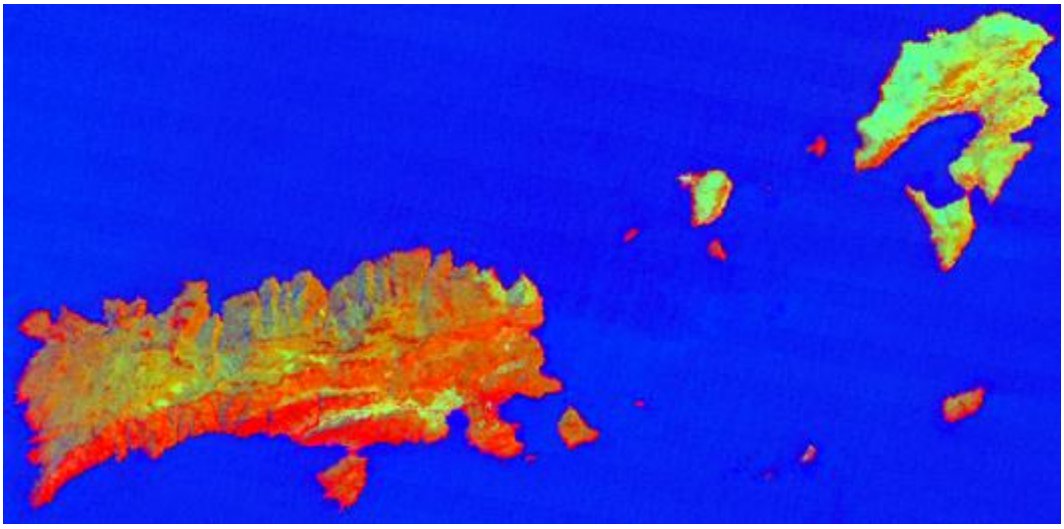

Figure 9 - The tasseled cap image of the ETM data. RGB combination of the bands 123.

3. In Situ Mapping.

Extended field work, including new geological mapping, GPS measurements and field data collection was undertaken in 2007 and 2008. All the small Islands around Halki were visited by a small boat (Figure 10) and mapped. Every tectonic line was checked and verified in the field. Every formation and all the geological boundaries were checked during the geological mapping and the boundaries were recorded digitally using the Arcpad GIS. The accuracy of the GPS measuremenwere ts was better than 3m (DGPS mode using EGNOS).

Formations of three geotectonic zones were recognized during the in Situ mapping. The bigger part of Halki Island is covered by limestone-dolomitic limestone of the Gavrovo Tripolis zone. At the south east coasts of the Island there are smaller appearances of limestone with silex and Flysch that belongs to the Ionian zone.

On Alimia Island the same formations with the exception of the Flysch of the Ionian zone were recognized. In addition an appearance of platy limestone with silex belonging to Pindos zone was mapped at the east part of the Alimia Island.

4. GIS

IGME has being implementing the project titled "Data digitizing for the Information System of IGME".

The project comprises the following basic objectives:

- Digitizing – vectorization of data derived from 265 analogical and 60 digital geological map sheets of scale 1:50.000.
- Data import into an integrated standardized geographic database in the Hellenic Geodetic Reference System (EGSA87) called "Hellas GDB50K" (Geological Database 50 K) covering the whole country.
- Database updating and service.

The geographic database is built in GIS Environment with the use of ArcGIS 9x software (ArcInfo version, ESRI). The used format for editing and data management is ArcGIS Geodatabase, a native data structure for ArcGIS software. It is a collection of geographic datasets of various types held in a common file system folder, a Microsoft Access database, or a multi-user relational database (such as Oracle, Microsoft SQL Server, or IBM DB2).

All geoinformation is compiled in feature classes and grouped in thematically organized feature datasets:

- Feature Dataset “formations”: It contains feature classes (point, linear, polygon geometry or annotation) concerning the geological linear objects and formations of the geological map.
- Feature Dataset “cross_section: It contains feature classes (point, linear, polygon geometry or annotation) concerning the crosses sections of the geological map.
- Feature Dataset “lithcolumn”: It contains feature classes (point, linear, polygon geometry or annotation) concerning the lithological column of the geological map.
- Feature Dataset “legendboxes”: It contains feature classes (point, linear, polygon geometry or annotation) concerning the legend boxes of the geological map.
- Feature Dataset “legend”: It contains feature classes (point, linear, polygon geometry or annotation) concerning the legend of the geological map.

Through the integration of the specific geological database additional processes will be carried out

- Integrate legends (general and detailed) and codification for the entire geographic database.
- Local adjustments of point, linear, polygon features in the overlapping area of adjacent map sheets
- Domains and subtypes creation, common for the entire geodatabase.
- Metadata creation for the geographic database based on ISO standards.

5. Conclusions

In the frame of a more general project, concerning the updating and homogenizing in a common geodata base the 1/50.000 geological maps of Greece, we published the geological map sheet of Halki Island.

The geoligcal formations of Halki Island and the small islands around it have been recognized and corresponded to respective zones of the External Hellenides.

Remote sensing data, GPS and GIS techniques were extensively used in order to facilitate and make more accurate the geological mapping. All the data are implemented in the IGME integrated geographic database.

6. Acknowledgments

This study was implemented in the frame of the project “COLLECTION AND DOCUMENTATION of GEOTHEMATIC INFORMATION’S FOR URBAN AND SUBURBAN AREAS IN GREECE – PILOT APPLICATIONS”. The program is funded from the Operational Program “Competitiveness” Priority Axis 7: Energy and Sustainable Development, Measure 7.3: Exploitation of natural resources and support in meeting environmental commitments. The Operational Program “Competitiveness” is co-funded by the European Regional Development Fund (ERDF).

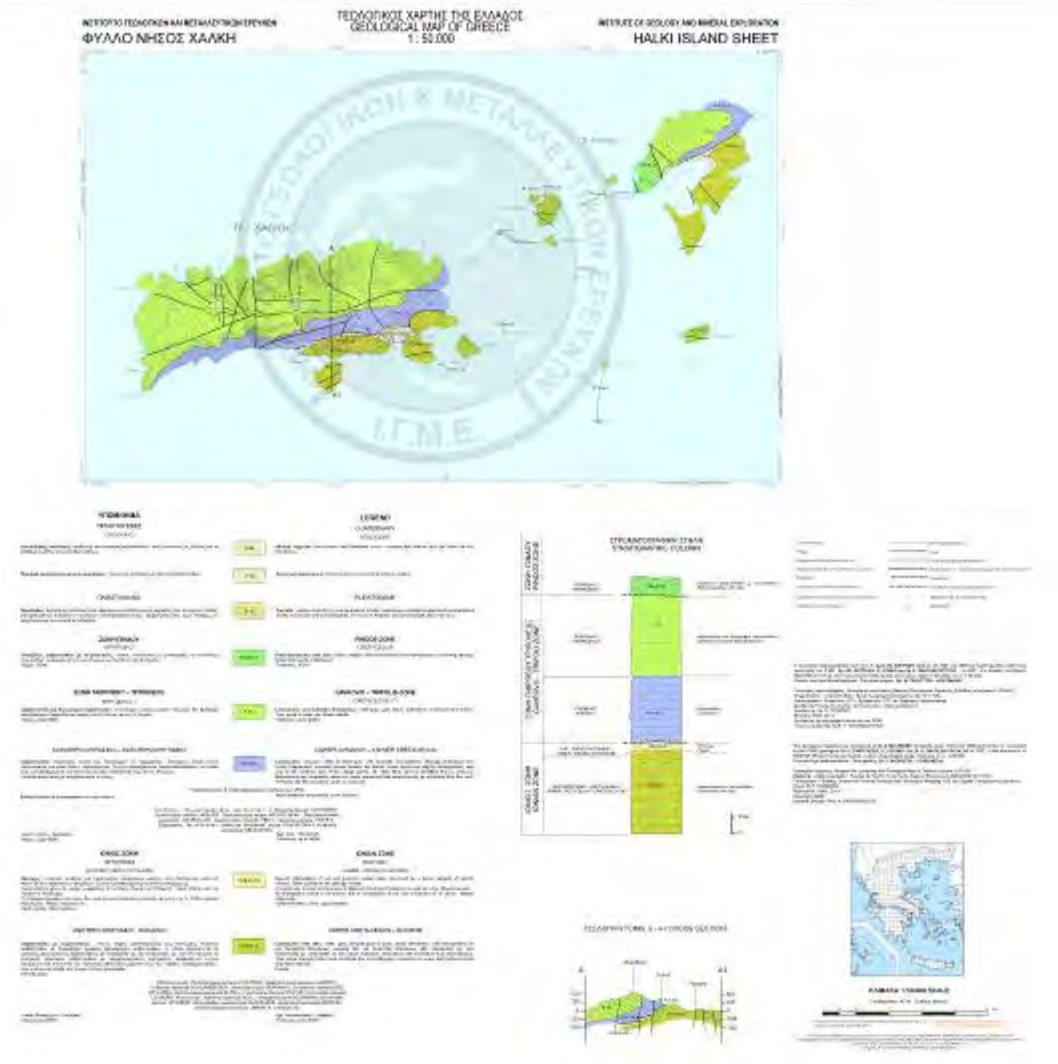

Figure 11 - The Geological map sheet Halki Island.

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