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TECTONIC STRUCTURE AND VOLCANIC CENTRES AT THE EASTERN EDGE OF THE AEGEAN VOLCANIC ARC AROUND NISYROS ISLAND.

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ABSTRACT

The recent volcanic activity at the eastern edge of the Aegean Volcanic Arc is limited within a neotectonic graben structure which is developed in an E-W general direction between the alpine basement of Kos Island to the north and the alpine basement of Tilos Island to the south. In between the boundary faults of the neotectonic graben there is an extended volcanic area comprising several individual volcanic centers, which penetrate through the thick post-alpine sedimentary deposits of the graben.

KEY WORDS: Aegean Volcanic Arc, Nisyros, Volcanic Centres, Tectonic Structure.

1.INTRODUCTION

The Aegean Volcanic Arc is the result of the subduction of the Eastern Mediterranean lithosphere below the active Hellenic margin of the European plate. The Volcanic Arc follows in parallel position successively the development of the Hellenic Trench, the Peloponnese-Crete-Dodecanese Island Arc and the Cretan back-arc molassic basin. The major recent or active volcanoes along the Aegean Volcanic Arc occur from Soussaki-Methana-Aegina and Poros in the west, through Milos and Santorini in the center, up to Kos and Nisyros in the east (Papanikolaou, 1986)(Fig. 1a).

Submarine volcanoes should exist all along the volcanic arc, in between the Aegean volcanic islands, as this was first documented in the case of Paphsanias Submarine Volcano in Epidauros Basin within Western Saronikos Gulf (Pavlakis et al 1990) and later in the case of the submarine area around Nisyros Island (Nomikou & Papanikolaou, 1999, 2000).

The understanding of the tectonic structure of the Kos-Nisyros volcanic area requires data both from on-shore and offshore studies, combining classical geology and marine geology investigations. In this paper, some answers on questions such as, which is the tectonic structure and how many volcanic centres exist in the area, will be given.

2. MORPHOLOGY

The morphology of the area is given in Fig.1 based on a digital elevation model, which has incorporated both onshore data from the Geographical Military Service and offshore data obtained from oceanographic surveys, effected during 1997-1999. Additional morphological data of high accuracy, using two kind of multibeam system i) Sea Beam 1120, 20 KHz for depths >500m and ii) Sea Beam 1180, 180 KHz for depths <500m on R/V Aegaeo, have been obtained during 2000. A first set of these newly obtained data for the area around Nisyros are given on Fig.4 within the description of the volcanic centres.

The main morphological features of the studied area are three zones of positive relief comprising Kos in the NW (843m elevation in Dikeos Mt), Nisyros (698m in Prophitis Ilias Mt.) and surrounding islets in the middle and Tilos (654m, Prophitis Ilias) in the SE. These zones subdivide the submarine area between Kos and Tilos in two basins with an average sea bottom depth of 600m. Consequently, the topographic differences between the Mountain ranges and the submarine basins are of the order of 1-1,5 Km.

In those cases where there is a high morphological gradient from the top of the mountain ranges to the edge of the submarine basins which results in very steep slopes, the zone of shallow depths (0-300m) is very narrow, as in the case of the southern coast of Kos Island. On the contrary, the area of the islets around Nisyros is characterized by extended shallow water depths which, as it will be shown in the next chapter, are occupied by volcanic formations.

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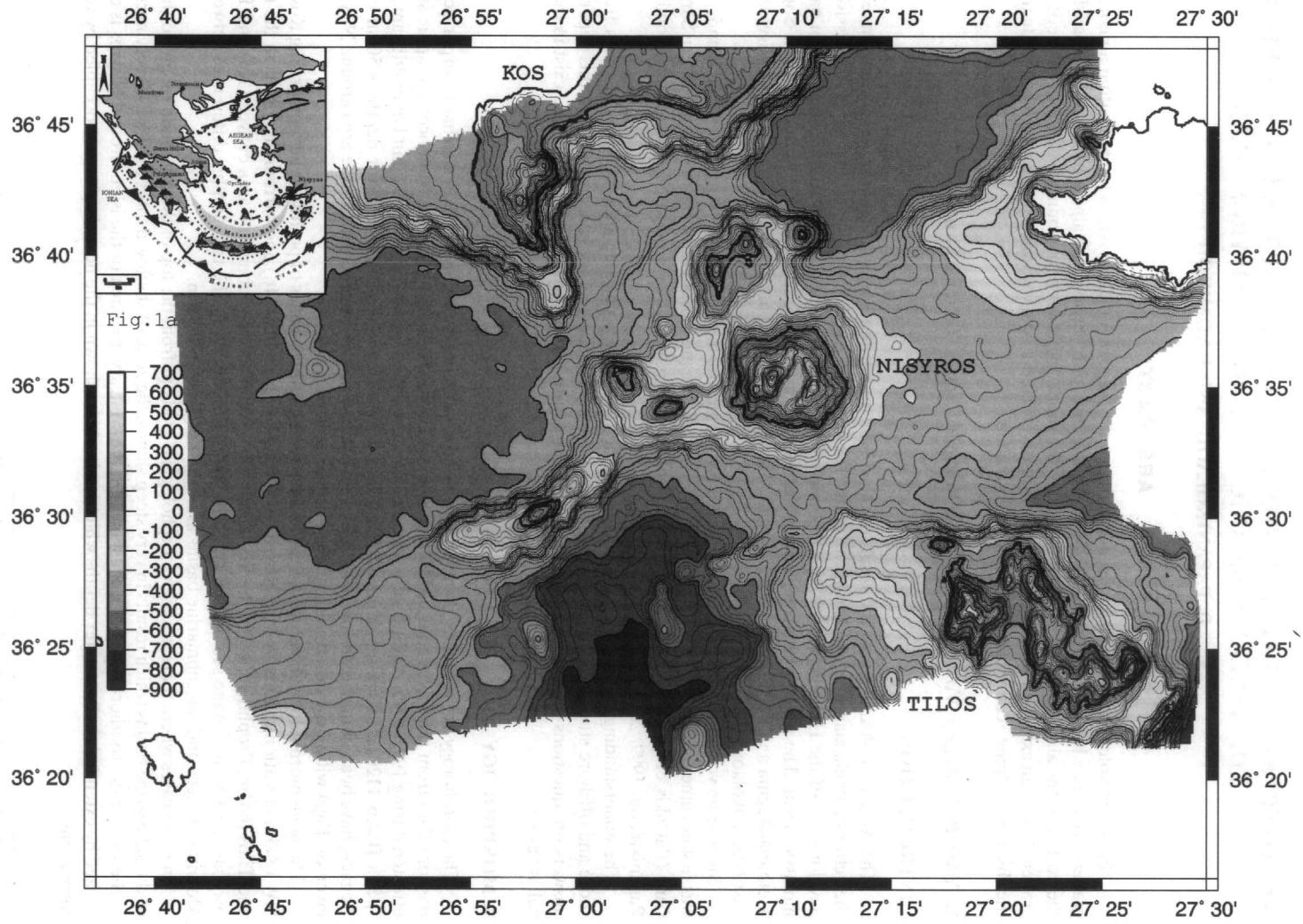
Fig 1: Digital elevation model of the Kos-Nisyros-Tilos area.
Fig 1a: Simplified sketch map of the present day geodynamic structure of the Hellenic Arc showing the position of Nisyros Volcano.



3. TECTONIC STRUCTURE

The geology of the area comprises: (i) alpine basement rocks, (ii) post-alpine sediments and (iii) Quaternary volcanic formations.

i) The Alpine basement rocks are cropping out on Kos Island and on Tilos Island in the south, each representing a neotectonic horst.

The alpine tectonic units of Kos comprise: (i) the metamorphic basement unit of Dikeos, which is of Paleozoic age (Desio 1931, Papanikolaou & Lekkas 1990, Papanikolaou & Nomikou 1999) and (ii) the upper non metamorphic nappes of Tripolis (Zia Unit), Pindos (Prof. Ilias Unit) and Eastern Kos Unit of the wild flysch. The alpine basement of Tilos belongs to the non metamorphic unit of Pindos (Desio 1931, Roussos 1978). From the neotectonic point of view it is important that the lowermost tectonic unit of the Paleozoic basement of Kos crops out at the top of Dikeos Mt. This fact implies that the northern marginal fault zone of Southern Kos, which separates the Kos neotectonic horst from the Eastern Kos submarine basin, is of the order of 3-3,5 Km (1,5 Km from the topographic difference plus 1,5-2,0 Km from the thickness of the upper non-metamorphic alpine units together with the thickness of the post-alpine sediments of the Eastern Kos Basin). On the contrary, the southern marginal fault of the area, separating Tilos Island from the submarine basins around Nisyros, has a smaller overall throw of the order of 1,5-2 Km.

In conclusion, the tectonic graben developed between Kos and Tilos comprises a thick sedimentary sequence together with volcanic formations of Quaternary age which have been subjected to an average subsidence of 2,5 Km.

The Kos tectonic horst to the north, is subdivided in three major neotectonic blocks (Fig.2). One uplifted block in the west, building up Kefalos peninsula, another relatively subsided graben in the middle, comprising the Antimachia platform and another uplifted neotectonic multiblock in the east, comprising the Dikeos Mt, where maximum elevation is observed and the Zipari and Kos neotectonic blocks which have suffered a stepwise relative subsidence to the north (Nomikou & Papanikolaou 1998).

ii) The Post alpine sedimentary formations which occur exclusively on Kos Island. They comprise formations of Miocene-Quaternary age, which built up exclusively the Antimachia neotectonic block. The presence of marine Pleistocene sediments all over the Antimachia platform indicates the timing of the uplift of this block above sea-level during middle-upper Pleistocene. This recent uplift formulated the present shape of Kos Island, unifing the two pre-existing islands of Kefalos in the west and Dikeos in the east.

iii) Quaternary volcanic formations mainly occur on Nisyros and surrounding islets. These volcanic formations are best exposed on Nisyros Island, where a first stratovolcanic cone was followed by a caldera formation and then by massive intrusive domes which built up the present-day Prophitis Ilias Mt. (Di Paola 1974, Papanikolaou et al. 1991).

On Kos Island there are volcanic rocks of Miocene and Pliocene age (Desio 1931) with outcrops amongst both alpine and post-alpine formations, followed by the Kefalos Middle Pleistocene volcanic sequence and finally by the vast extension (2/3 of Kos) of the Upper Pleistocene Kos Ingrimbrite (165 Ka) (Smith et al 1995, Allen et al 1999).The volcanic centre which yielded the Kos ingrimbrite is not known but it is estimated in the sea-bottom somewhere nearby Yali Island.

The above general structure of the tectonic graben between Kos and Tilos, with the massive volcanic intrusions in the middle of the graben around Nisyros, is shown on the tectonic profile from Kefalos to Tilos (Figure 2a). The oceanographic surveys provided a large number of lithoseismic profiles throughout Kos-Tilos marine area using single channel and multi channel air-gun system of 24 channel steamer with 2 air-guns of 1 litre. Two representative, for the overall neotectonic structure, lithoseismic profiles are given on Fig.3. The first profile at the eastern part of the area, starts from the southern slopes of the Dikeos Mt, showing the northern marginal fault zone and continues through the sediments and intercalated volcanics of the Eastern Kos Basin and the Eastern Nisyros Rise, up to the Tilos marginal fault zone in the south. The second profile at the western part of the area, starts from the southern marginal fault of Kefalos peninsula and continues throughout the volcano-sedimentary sequence of the western Kos basin, the Pachia Volcanic Dome, and the volcano-sedimentary sequence of the southern Nisyros Basin, up to the westward prolongation of the marginal fault zone of Tilos.

4.VOLCANIC CENTRES

Until recently only Nisyros and Yali were considered in the geological literature, as recent or active volcanoes at the eastern edge of Aegean Volcanic Arc. Our studies including studies both onshore and offshore concluded that after the Kefalos Volcano, which was activated before 0,5 Ma and the volcanic eruption which

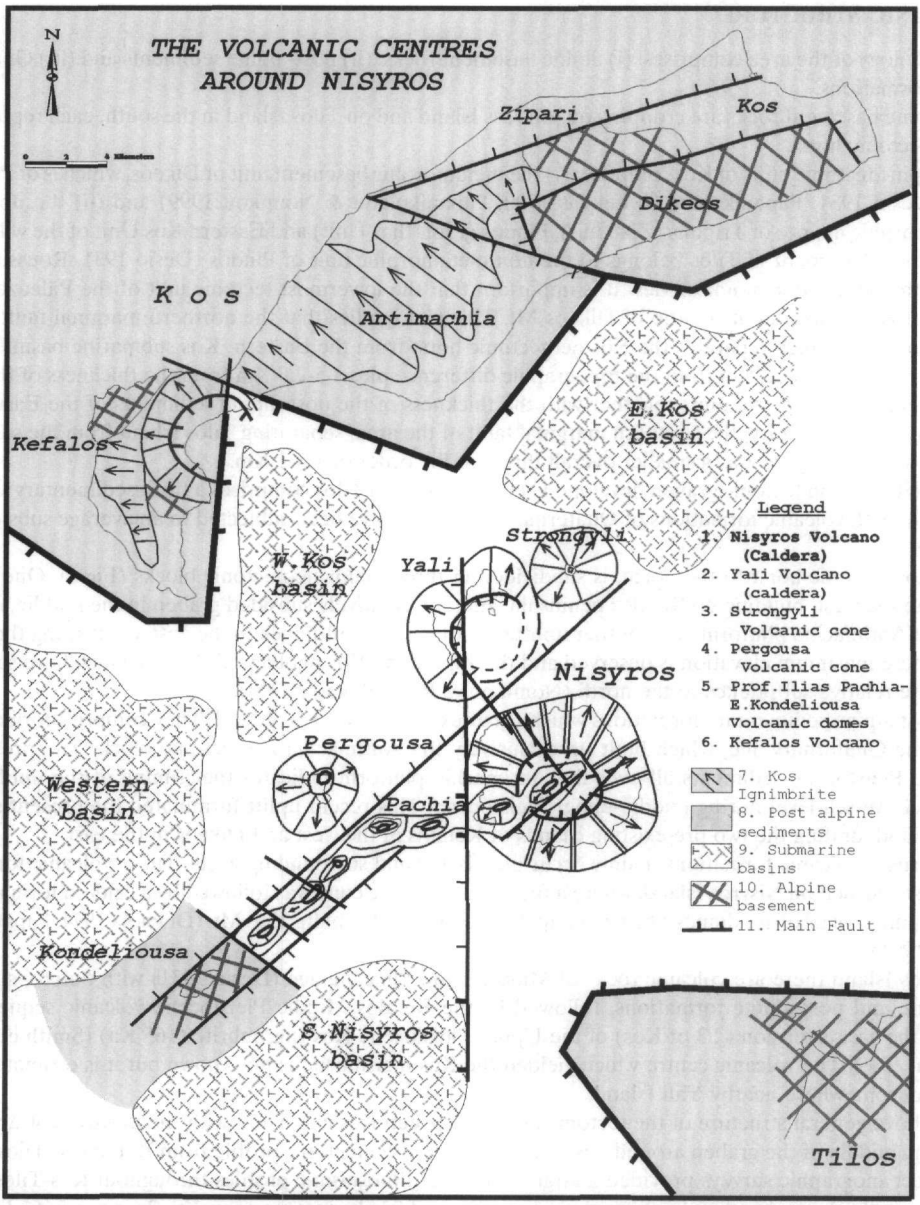


Fig 2: Schematic map of tectonic structure and the volcanic centres around Nisyros.

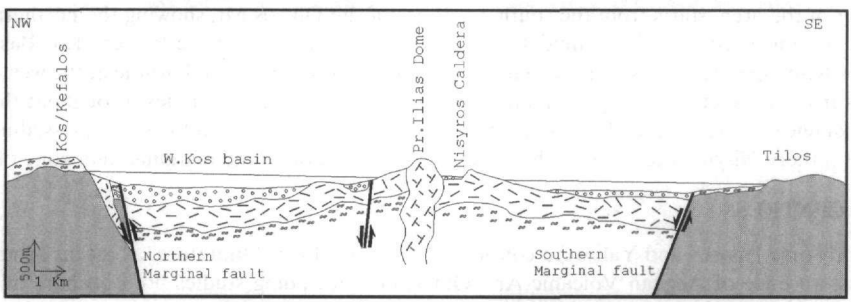


Fig 2a: Schematic tectonic profile through Kefalos-Nisyros-Tilos.

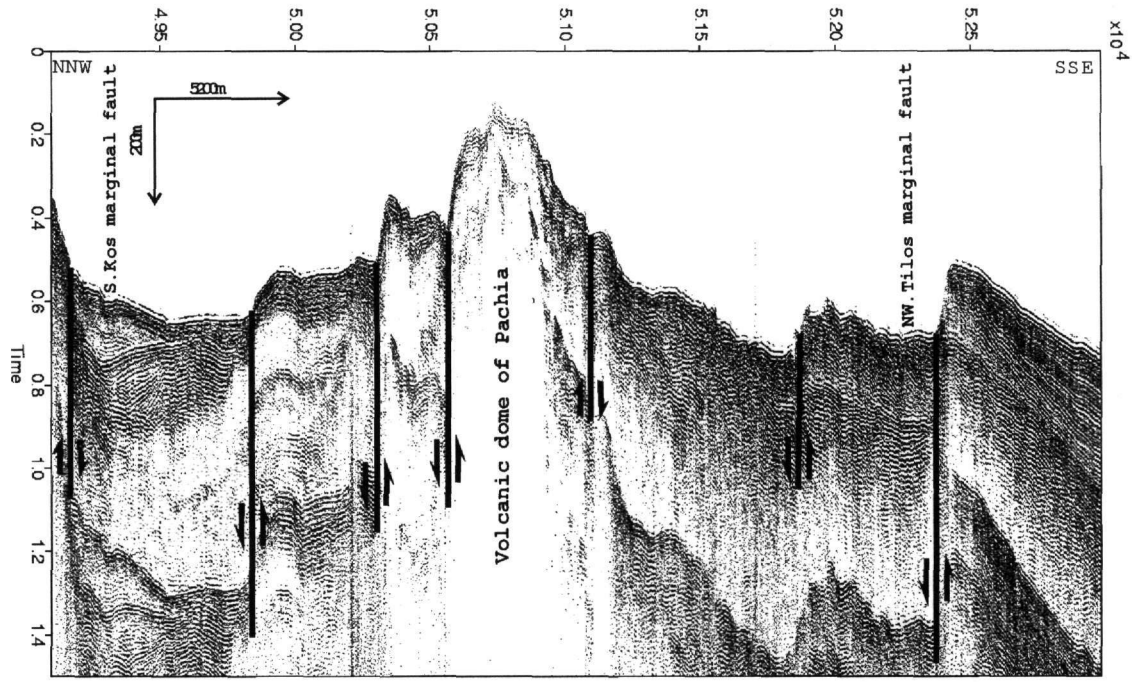


Fig 3a:Representative lithoseismic profile of the tectonic graben between Kos-Tilos through Pachia Volcanic Dome.

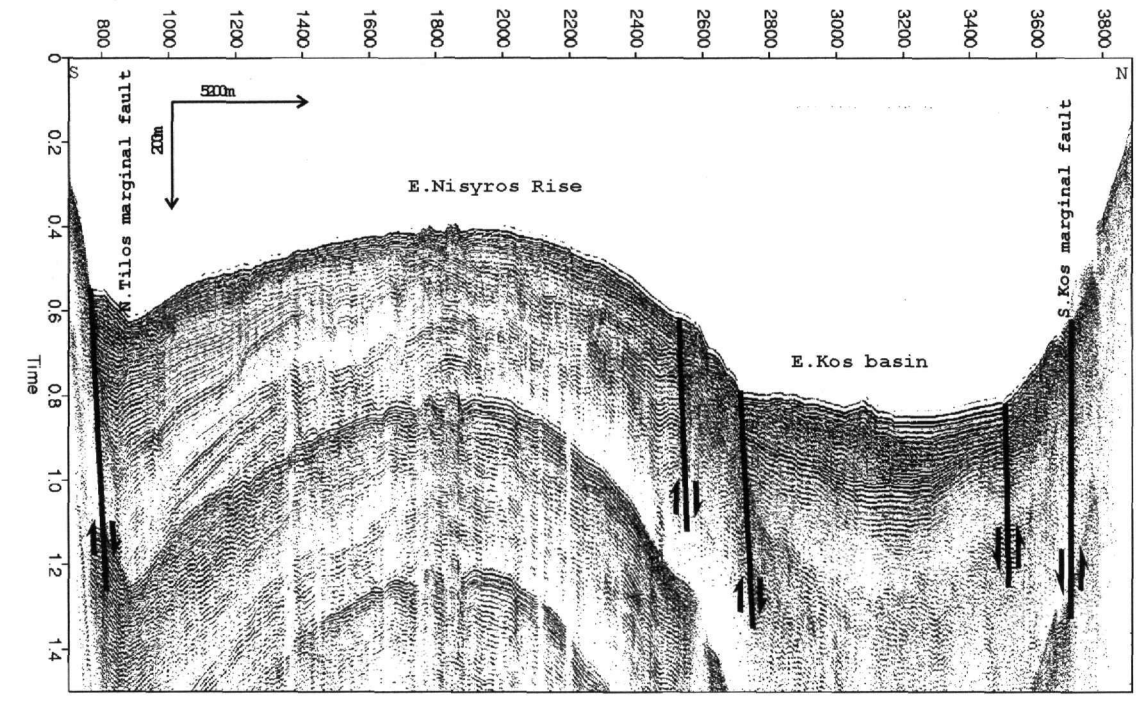
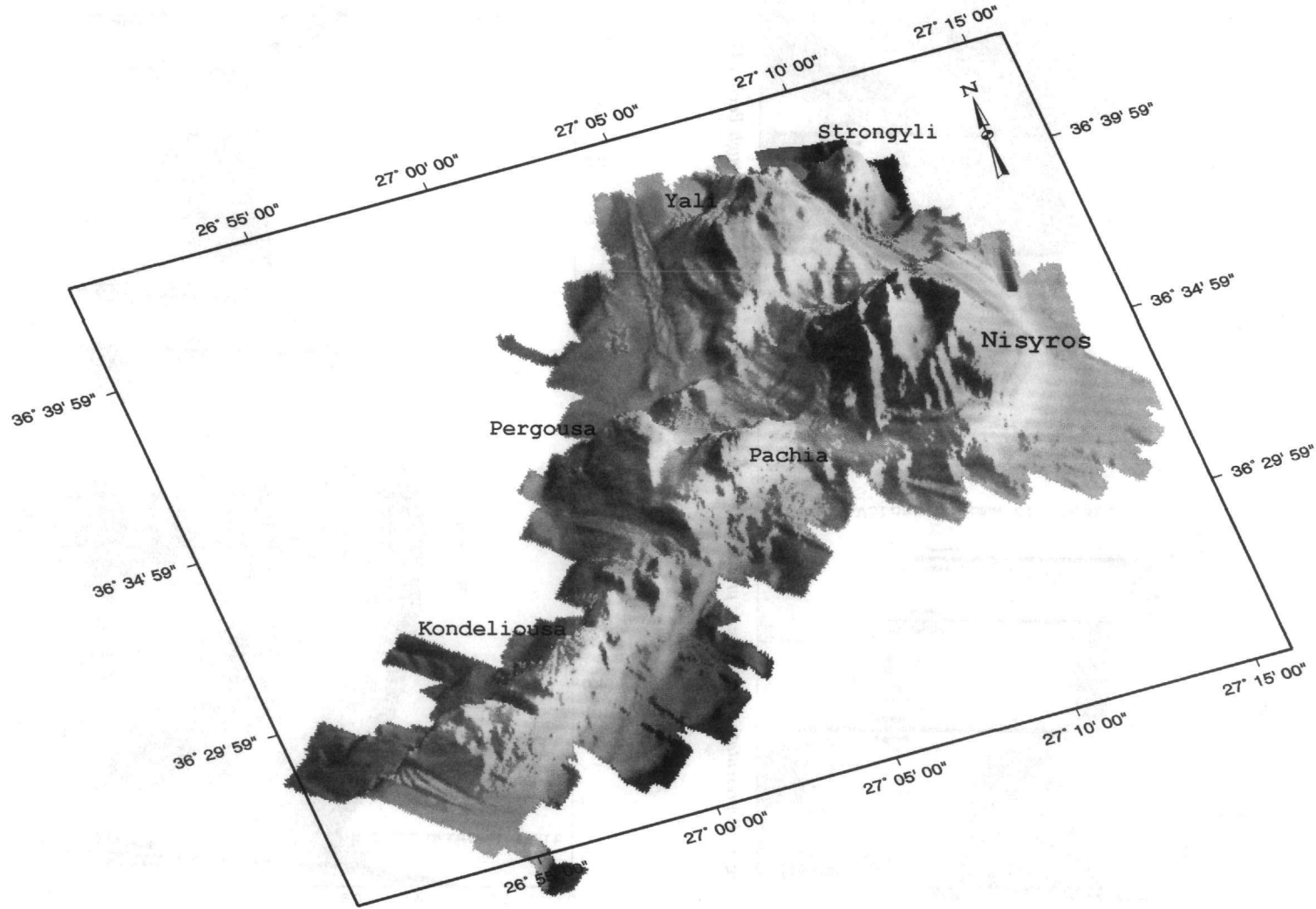


Fig 3b:Representative lithoseismic profile of the tectonic graben between Kos-Tilos through Eastern Nisyros Rise.

Fig 4: Perspective image of Nisyros and neighbouring volcanic islets. View from SW.



resulted in the deposition of the Kos ignimbrite before 0,165 Ma, the volcanism has been developed in the marine area around Nisyros with the formation of individual volcanic centres, each of them exhibiting a special geometry and evolutionary stage (Fig.2). These are:

i) The Nisyros Volcano which was characterized by a stratovolcanic cone, whose eruption created the Nisyros caldera. The largest present-day phreatic crater of Stephanos occurs within the Nisyros caldera.

ii) The Yali Volcano which exhibits a partly submerged caldera. The two parts of Yali are dislocated by a post-caldera N-S fault. The Western Yali is made of two successive pumice formations whereas the Eastern Yali is made of obsidian glass covered by a pumice formation (equivalent (?) to the upper pumice of Western Yali).

iii) The Strongyli Volcanic Cone, which starts from –600m depth of the sea-bottom up to +120m of the top of the present day Strongyli Islet where a volcanic crater of 300m diameter is observed (pre-caldera stage).

iv) The Pergousa Volcanic Cone, which is made of stratovolcano type formations with alternative lava flows and pumice layers (pre caldera stage).

v) The Volcanic domes of Prophitis Ilias on Nisyros Island (post-caldera stage) and the similar volcanic domes of Pachia Islet and the submarine volcanic domes to the east of Kondeliousa Islet.

The overall morphology of the above volcanic centres around Nisyros is shown on a 3D view from SW on Fig. 4. This view is based on data obtained from multi-beam bathymetric survey during April 2000, combined with onshore hypsometric data.

A digital submarine picture showing a volcanic crater of 8-10m diameter and 3,5-4 m height at 240m depth from the northwestern slopes of Strongyli Volcanic Cone is given on Fig.5 This picture was taken during a dive with submersible THETIS of NCMR during April 2000.

5. CONCLUSIVE REMARKS

A number of volcanic centres has been described around Nisyros Island. All these volcanoes have been developed within a neotectonic graben formed by a subsidence of the order of 2,5 Km between the marginal fault zones of Southern Kos and Northern Tilos. The volcanic centres are built up from a base level of -600m, which is the level of the mean sea-bottom of the marine basins up to +700m summit of Prophitis Ilias on the top of the post-caldera volcanic dome of Nisyros Island. Thus, a volcanic relief of more than 1300 m has been produced by the geodynamic processes of Upper Pleistocene - Holocene. The different stage of volcanic development of each centre as pre-caldera volcanic cone, caldera or post-caldera domes implies the existence of a permanent mechanism of volcanic activity during the last 160 Ka and new possibilities for long-term prediction of volcanism in the area.

Fig 5: Digital submarine picture showing part of the volcanic crater (8-10m diameter and 3,5-4m height) at Strongyli Volcano at 240m depth.

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