
The Volcano of Nisyros Island

Dr. Paraskevi Nomikou, Lecturer of Oceanography
Faculty of Geology and Geoenvironment
National and Kapodistrian University of Athens

Nisyros in the Greek Mythology

According to the Mythology, Poseidon, helping Zeus while he was combating the Titans, he was pursuing the terrible giant Polyvotis on the beachside and in the seas. Arriving in front of the island of Kos he detached with his trident a part of the island, he launched it against Polyvotis and he buried him underneath. The island of Nisyros is created by this fragmentary part of the island of Kos. The volcano was created in the place where the mouth of Polyvotis is and the frequent earth tremors and are also due to the continuous laboured breathing of the buried Titan's chest. A wonderful myth which reveals that our ancestors knew that Nisyros was a volcano and its rocks were similar to those of south-western Kos. They also knew or felt that the frequent local tremors, accompanied by crashing sounds, which tormented the island in those days, were related to the same mechanism which had given birth to the island itself.

Since Neptune was the creator of the island he remained its protector and this justifies the existence of Neptune's temple in the island and of several coins of Nisyros which represented the head of the god of the sea. The myth expresses the relations between the islands of Nisyros and Kos starting from the mythical years up to this day, political, moral, social and economical bonds.

The island's name probably belongs to the pre-hellenic place-names of the Aegean Sea. In Homer we find references to the participation of the inhabitants of Nisyros, along with other island inhabitants, in the Trojan expedition. Names of the people of Nisyros can also be found in the fiscal lists of the Athenian alliance. They worshiped Apollon the Delphinios, like the pelagic Apollon. A temple dedicated to him is located in the village that today is called Palloi where old thermal springs of the island can also be found. Remaining votive steles witness the exceptional position held by the Milichios Zeus, the goddess of Chance, Hermes etc. in the worship of the ancient inhabitants.

Geodynamic Setting

The Hellenic Volcanic Arc has developed in the back arc region of the Hellenic subduction zone, parallel to and about 150km north of the Hellenic Arc (McKenzie, 1970; Le Pichon & Angelier, 1979). It is the result of the subduction of the East Mediterranean oceanic lithosphere below the European continental plate, at least during the last 45 Ma (Papanikolaou, 1993). The geodynamic structure of the Hellenic Arc includes the Hellenic Trench, which is a 1500- km-long arcuate series of troughs extending from the Ionian Sea in Western Greece to the Lybian Sea, south of Crete and terminating southeast of Rhodos Island. It also includes the Island Arc represented by the Peloponnese, Crete and Dodekanese Archipelago, and the back-arc molassic basin of the Cretan Sea. The Hellenic Volcanic Arc has developed parallel and behind of the Island Arc.

Recent volcanoes occur on Soussaki, Methana, Aegina and Poros to the west, on Milos and Santorini in the centre and on Kos and Nisyros to the east. Submarine volcanoes have also

been found in the Epidauros Basin in the western Saronikos Gulf (Pavlakis et al., 1990) and in the Anydros Basin northeast of Santorini (Perissoratis, 1995; Alexandri et al, 2003) and in the submarine area around Nisyros (Nomikou et al 2004).. The volcanoes of the Hellenic Arc were especially active in the Late Pleistocene–Holocene, with some eruptions known in historical times (Fytikas et al., 1976; Liritsis et al., 1996).

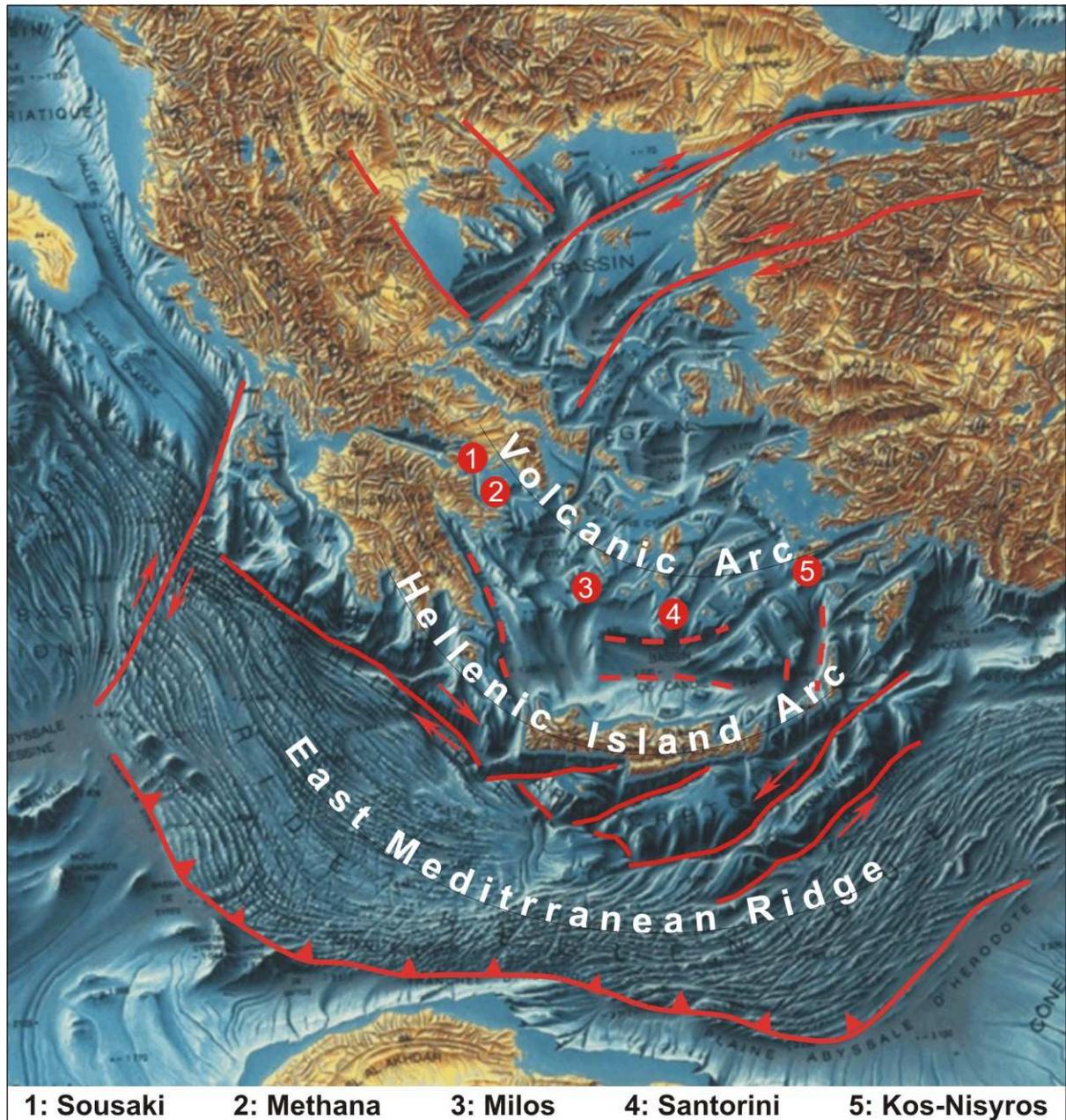


Fig. 1: geodynamic setting of the Aegean – Eastern Mediterranean Region. Red dots with numbers mark the active volcanoes of the Hellenic Volcanic Arc.

The eastern sector of the Hellenic Volcanic Arc, including the islands of Kos, Yali and Nisyros, resulted from the northeastward directed subduction of the Eastern Mediterranean lithosphere below the active Hellenic margin of the European plate. It is a very active sector, featuring the largest volumes of volcanic products in Late Pleistocene–Holocene times. Major magmatic activity began at least 0.16 Ma ago (Keller et al.,1990), producing the largest eruption in the Eastern Mediterranean represented by the “Kos ignimbrite”, which covered an

area of more than 3000 km². The centre of this eruption is not known with accuracy but it is probably located in the submarine area north of the Yali islet, a few kilometres northwest of Nisyros (Nomikou, 2004).

The geology of Nisyros

Nisyros has a spectacular relief of volcanic scenery. The island's shape is a truncated cone with a base diameter of 8 km and a caldera in the middle of the island with 4 km diameter (Fig. 2)

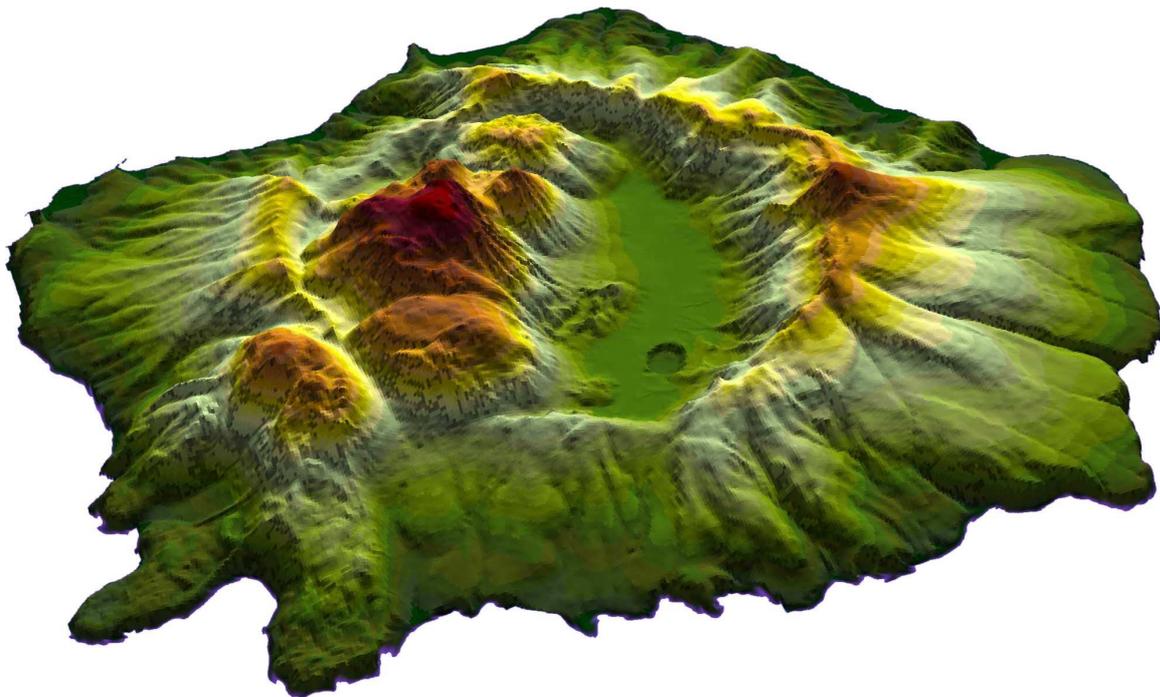


Fig. 2: Digital Elevation Model (DEM) of Nisyros volcano (Nomikou 2004). The shape of the island reveals the characteristic circular, conical geometry of the active volcanoes, with the large caldera on the top of the volcanic cone.

The island of Nisyros is exclusively made of Quaternary volcanic rocks, represented by alternating lava flows, pyroclastic layers and more viscous lava domes, ranging in age from 200 to 25 ka. Nisyros forms a truncated cone with a base diameter of 8 km and a central caldera, 4 km in diameter. Basement rocks made of carbonates and marbles were found at depth of 600 m in a well located in the northwestern part of the caldera and at 1000 m below the southeastern part by geothermal drillings (Geotermica Italiana, 1983, 1984). The infilling of the caldera above this basement is made of lacustrine, alluvial and tephra deposits.

The evolution of this volcano has been described first by Martelli (1917), Desio (1931), Davis (1967) and Di Paola (1974), and more recently it has been divided into five major stages (Papanikolaou et al., 1991; Vougioukalakis, 1993; Nomikou, 2004; Vanderkluyesen et al., 2005; Volentik et al., 2005):

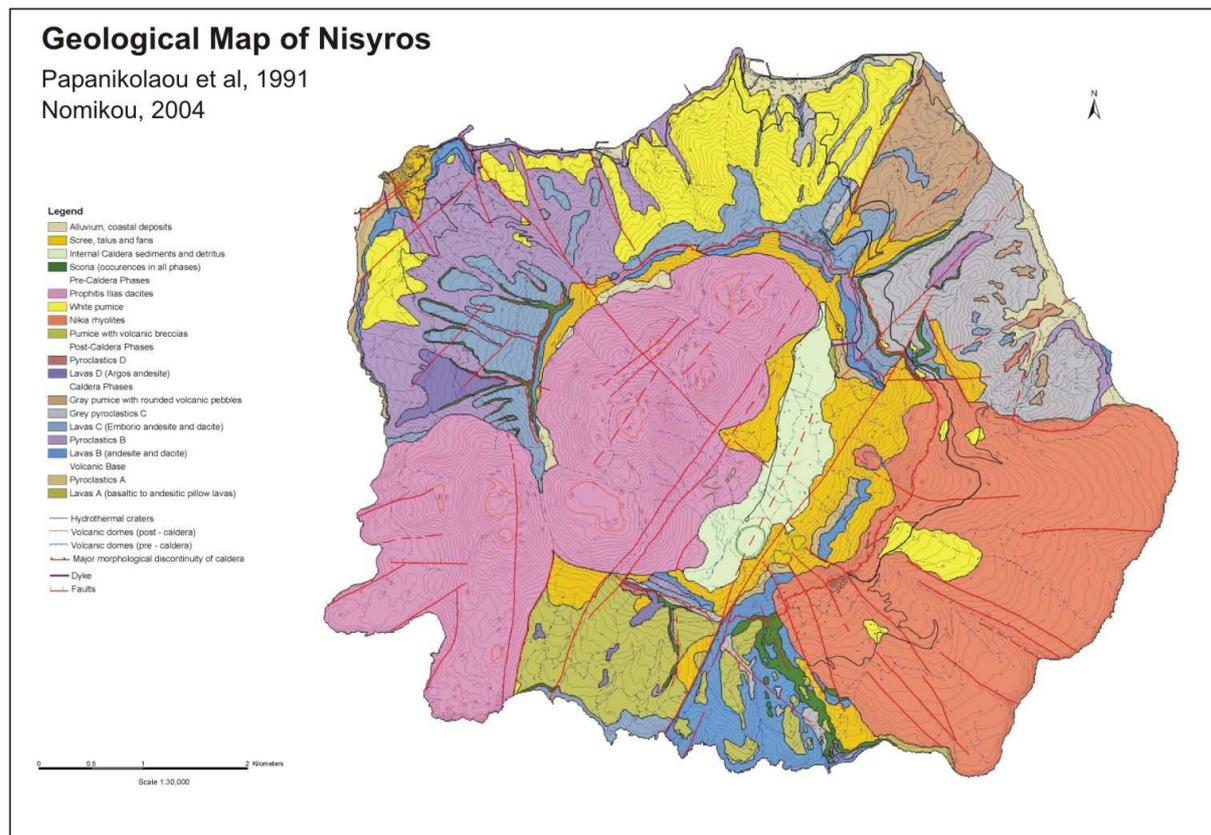


Fig. 3: Geological Map of Nisyros after Papanikolaou et al (2001) and Nomikou (2004)

(1) an underwater volcano, with erupting basaltic and andesitic pillow-lavas, built up the lower volcanic rocks visible on the northern coast near Mandraki;

(2) A 500–700 m high stratovolcano grew on top of these partly submarine lavas for a period of more than 100 ka;

(3) after several eruptive phases of gas and steam explosions, two major rhyodacitic plinian eruptions covered the whole island with pyroclastic flows and pumice falls;

(4) subsequently, a major central, vertical collapse of the volcano leaved a large caldera at <20 ka BP (Limburg and Varekamp,1991); and

(5) during pre-historic times, the western part of the caldera depression was filled with a series of rhyodacitic domes, the highest of which, Profitis Ilias, rises 698 m a.s.l.

No volcanic activity is known to have occurred on the island after the formation of the domes for at least 25 ka; the only reported historical explosions are related with the formation of several phreatic craters inside the caldera, such as Alexandros, Polyvotis, Stephanos, Phlegethon and Achelous, which are still emitting fumaroles. Violent earthquakes, gas detonations, steam blasts and mudflows accompanied the most recent hydrothermal eruptions in 1871–1873 and 1887 AD (Marini et al., 1993). During this activity some people were slightly injured and minor damages were caused to the houses.



Fig. 4: View of the caldera of Nisyros with the domes of Prophitis Ilias (left) and Stefanos crater in the right.

After several years of repose, an intense seismic activity started at the end of 1995 and lasted up to 1998, with the largest event recorded on 27 August, 1997 with an Ms:5.3 (Papadopoulos et al., 1998). Minor damages were reported along the western edge of the Mandraki town related to the Mandraki fault. The on land geological, tectonic and morphological data show that the Mandraki fault throw is 80-100 m and its length about 2 km. Nomikou & Papanikolaou (2010) have shown that the fault continues northward into the Yali-Nisyros strait where it has created a 100m high submarine escarpment.

Evidence from seismicity and SAR interferometry suggests that the presently active part of the Kos–Nisyros volcano-tectonic complex is located at the NW coast of Nisyros Island, and that most uplift deformations occurred in the northwestern flank of the volcano (Sachpazi et al., 2002; Lagios et al., 2005).

The overall structure of Nisyros comprises several blocks kinematically characterised by relative uplift (horst-type) or relative subsidence (graben-type). The largest offsets have been recorded at the NE-striking and NNW-striking faults. Among the largest faults, the NE-striking structures affect the caldera zone, whereas the NNW-striking faults are mostly limited to the northwestern extra-caldera zone (Tibaldi et al, 2008).

GPS stations were established on Nisyros Island over all the main tectonic blocks, aiming at monitoring the deformation field. Measurements started in June 1997 and recorded important displacements, both in the horizontal and the vertical axes, of the order of 10–40 mm/y (Nomikou et al., 1999; Lagios, 2000). A detailed geomorphological and biological study of the coasts of Nisyros Island, combined with radiocarbon analysis of collected samples, provided evidence of land uplift along the northern and western coast, at a minimum, though increasing rate of 1.7 mm/yr during the last 2,000-3,000 years (Stiros et al, 2005). This observation is in agreement with GPS data and the late Quaternary uplift deduced from coastal, tectonic and volcanological data (Tibaldi et al, 2008; Nomikou & Papanikolaou, 2010). Marine geological surveys in the region around Nisyros have revealed the presence of a complicate submarine topography with steep slopes separating relatively deep basins from elongate ridges and conical structures (Fig. 5) (Nomikou, 2004; Nomikou & Papanikolaou, 2010).

Swath bathymetry survey and seismic profiling led to the discovery of a large number of submarine volcanic centres, most of which emerge as small volcanic islets. Figure 5 shows the three-dimensional perspective visualization of the swath bathymetry and topographic relief of the Nisyros Volcanic Field. 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 mean depth of the marine basins up to +700m, which is the altitude of Prophitis Ilias's 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 (Papanikolaou & Nomikou, 2001).

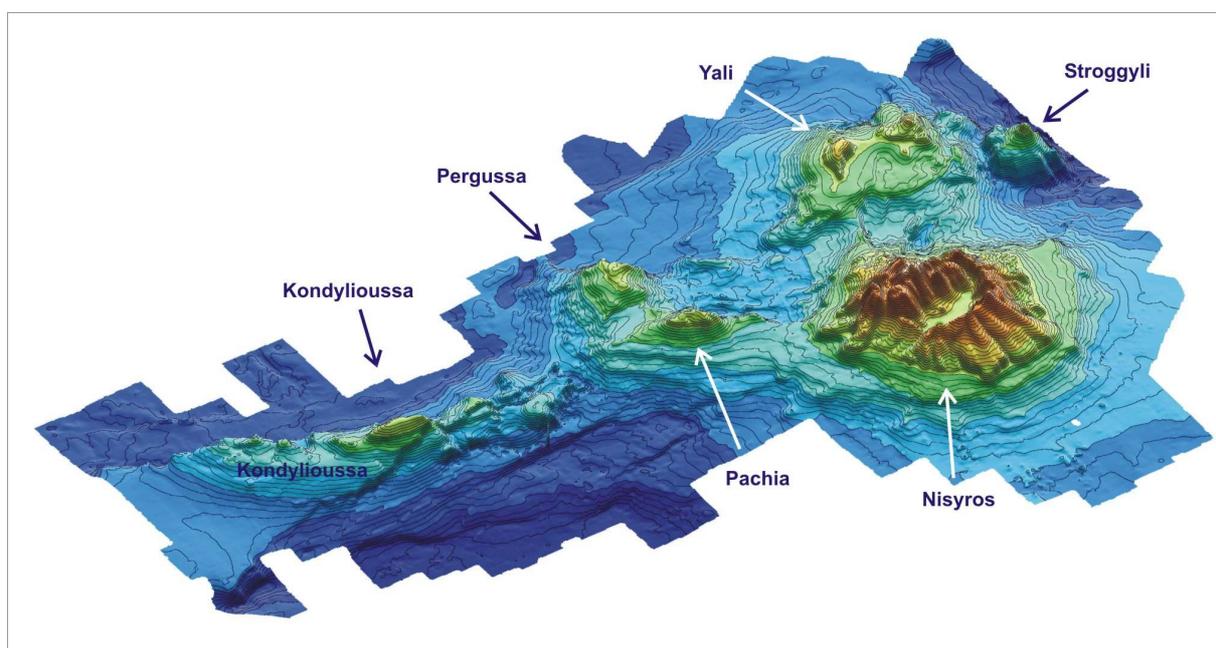


Fig. 5: Three dimensional image of the on- / offshore relief of the Nisyros volcanic field after Papanikolaou & Nomikou (2001) and Nomikou (2004). Note that the volcanic centres and domes are aligned NE-SW, parallel to the main fault zones.

Hydrothermal Craters

Hydrothermal craters are formed by steam and gas explosions, mainly due to steam overpressure in a hydrothermal system close to the surface, within or in the vicinity of a volcanic caldera. Such explosions can occur if fresh hot magma is injected from deep crustal magma reservoirs into a shallow magma chamber. There, the magma is able to release gases due to lower lithostatic pressure and transmit heat to the surrounding hydrothermal system. Several volcanic centres are present in the island. They comprise eroded centres, mostly located along the caldera walls and in the extracaldera volcano flanks, and younger centres located on caldera floor. The craters are concentrated between the domes and the southern caldera wall. They result from hydromagmatic explosions and have been dated at pre-historic to historical times (Caliro et al., 2005, and references therein), thus their original morphology is intact.

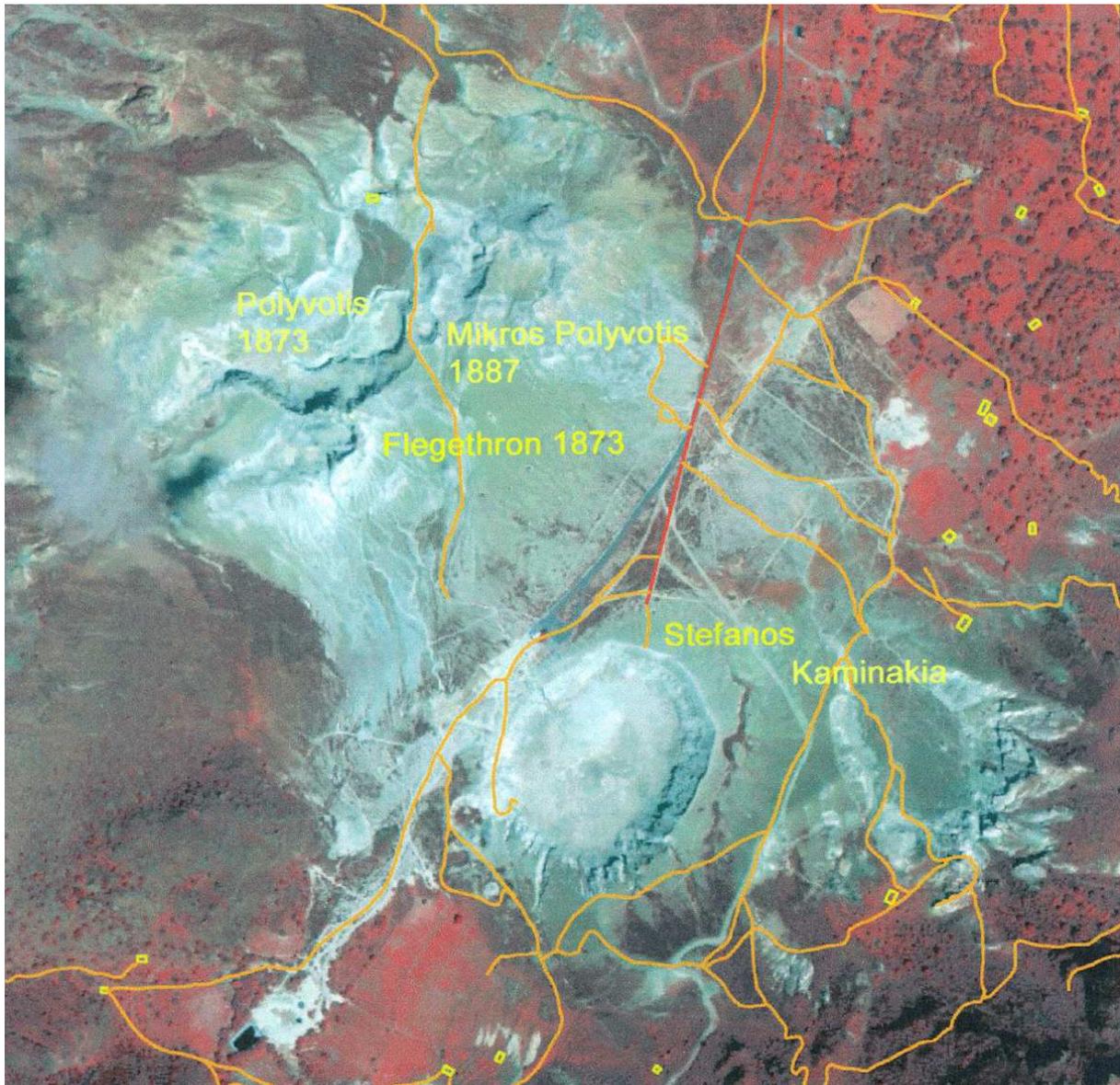


Fig. 6: Orthorectified ICONOS satellite image of the craters within the caldera of Nisyros volcano.

The biggest and most spectacular crater is called **Stefanos**, and is one of the biggest and best preserved hydrothermal volcanoes in the world. Its form is ellipsoidal with 330 m length and 260 m width. The walls of the crater are 30 m high. It is estimated that it cannot be older than 3000-4000 years. A field of fumaroles is located on the caldera floor, inside Stefanos crater. Most gases are emitted by fractures directly cropping out or by vents whose formation is similar to the evolution of tectonic sinkholes produced by erosion processes along fractures and fissures.



Fig. 7: Stefanos crater viewed from Nikia (Image courtesy P. Nomikou). It is one of the largest and best preserved hydrothermal craters in the world. Ellipsoid in shape, 330m long by 260 m wide and 27 m deep , is visited by a large number of tourists every summer.

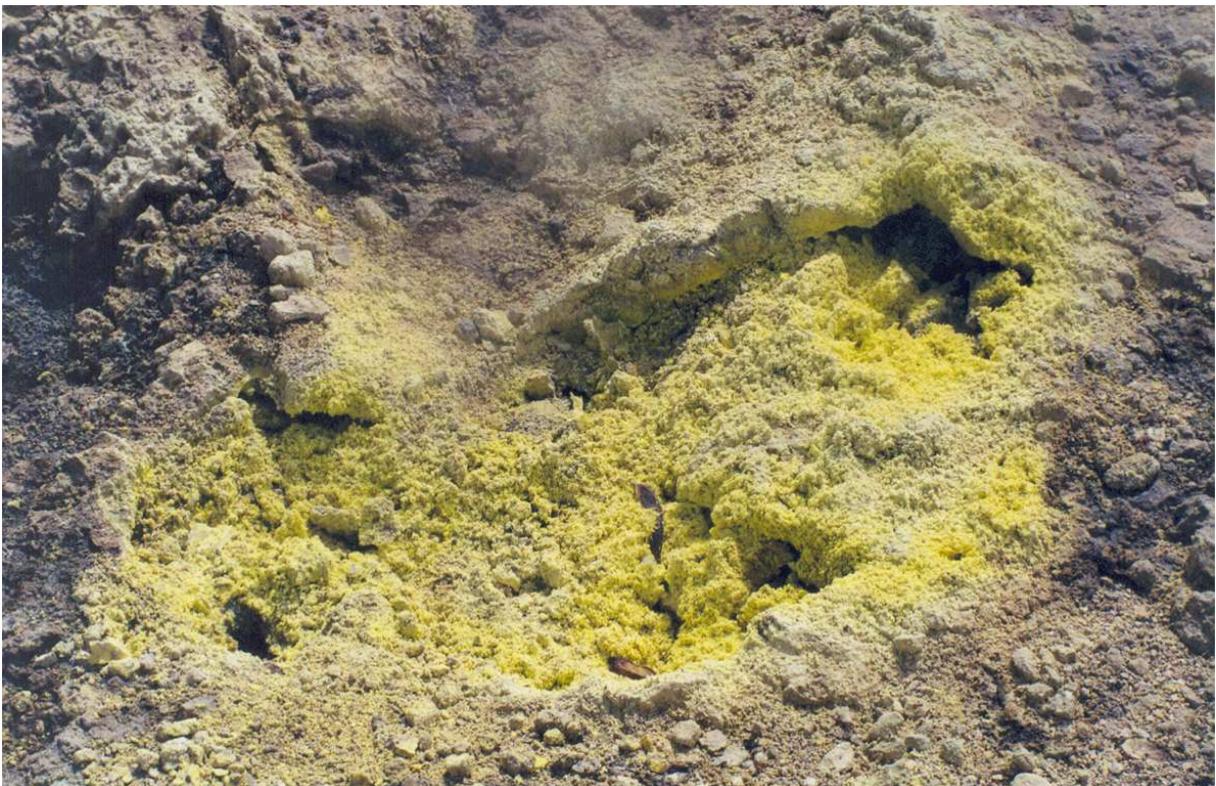


Fig. 5: Fumaroles with sulfur crystals on the floor of Stefanos crater (image courtesy P.Nomikou).

Big Polivotis is the second largest crater (300 X 150 m) and is believed to be younger than Stefanos. Next to Stefanos is the **small Stefanos** or **Andreas**. **Logothesis** is the name of

the oldest crater in the region. **Alexandros** is the crater which was widened after the earthquake of 1873. The last hydrothermal eruption reported in Nisyros is the one of 1887, which created the crater **Small Polyvotis**.

The most recent hydroclastic eruptions in 1873 and 1888 were accompanied by earthquakes, gas detonations and fire. The latter effects are due to high gas emanations of H₂S, CO₂, H₂ and CH₄ from fracture zones which cut the caldera. The craters remained filled after the explosions with hot saline rich waters, sulfur deposits and debris. After evaporation of water a flat bottom covered with mud remained.

Recent Hydrothermal eruptions

1871: At the end of November **1871** a violent earthquake took place (with no damage reported), followed by a series of detonations. Red and yellow flames rose over the island. Fragments of rocks flew over the highest peaks and down into the sea; the fields within the caldera were covered in white dust. The activity of the fumaroles inside Stefanos crater decreased, and that of fumaroles inside Polyvotis increased

1873: Numerous violent seismic shocks were felt by the inhabitants. Although in three villages the walls of some houses were partially collapsed, no casualties were reported. The monastery at Mandraki, situated on an outcrop of trachytic conglomerate, suffered minor damage. Meanwhile, a few yards from the shore, the sea turned a whitish colour; it emitted torrents of steam, mixed with hydrogen sulphide and a great underwater fissure opened. Eruptions continue for several days within the craters of Flegethron and Polyvotis. Dark fluid mud with thickness of 3m discharged from Flegethron and moved southwards, traveling a distance of 500m. The steam and hot water drench the branches of the trees and when they evaporate leave stalagmites of salt.

Sailing from Rhodes to Nisyros lasts about 2,5 hours. From Mandraki, the port of Nisyros island we will drive through the northern flank of the volcano and reach the caldera rim near Emporio. The view from there to the caldera is spectacular. We will continue the road down the caldera wall and will stop at Lefteri's kiosk. From there we will follow the path to Stefanos crater and end up on the floor of it. There we will be able to feel the heat coming from earth's interior and admire the venting fumaroles and the sulfur crystals formed around them.

References

- Alexandri, M., Papanikolaou, D., Nomikou, P., and Ballas, D., 2003. Santorini volcanic field – New insights based on swath bathymetry. Abstracts IUGG 2003, Sapporo, Japan.
- Caliro, S., Chiodini, G., Galluzzo, D., Granirei, D., La Rocca, M., Sacorotti, G., Ventura, G., 2005. Recent activity of Nisyros volcano (Greece) inferred from structural, geochemical and seismological data. *Bulletin of Volcanology* 67, 358–369.
- Davis, E.N., 1967. Zur Geologie und Petrologie der Inseln Nisyros und Jail (Dodekanes). *Praktika of the Academy of Athens* 42, 235–252.
- Desio, A., 1931. Le isole italiane dell' Egeo. *Memorie Carta Geologica d'Italia* 24.
- Di Paola, U., 1974. Volcanology and Petrology of Nisyros Island (Dodecanese, - Greece). *Memorie dell'Istituto Geologico dell'Universita` di Padova* 7.
- Fytikas, M., Guliani, O., Innocenti, F., Marinelli, G., Mazzuoli, R., 1976. Geochronological data on recent magmatism of the Aegean sea. *Tectonophysics* 31, 29–34.
- Geotermica Italiana, 1983. Nisyros 1 geothermal well, PPC-EEC report, 160 pp.
- Geotermica Italiana, 1984. Nisyros 2 geothermal well, PPC-EEC report, 44 pp.
- Keller, J., Rehnen, T.H., Stadlbauer, E., 1990. Explosive volcanism in the Hellenic arc. A summary and review. In: *Proceedings of the third scientific congress "Thera and the Aegean World III"*. Earth Sciences, vol. 2, pp. 13–26.
- Lagios, E., 2000. Intense crustal deformation rates on Nisyros Island (Greece), deduced from GPS studies, may foreshadow a forthcoming volcanic event. In: Balassanian, S., Cisternas, A., Melkumyan, M. (Eds.), *Proc. 2nd Int. Conf. on Earthquake Hazard and Seismic Risk Reduction*. Kluwer, Dordrecht, pp. 249–259.
- Lagios, E., Sakkas, V., Parcharidis, I., Dietrich, V., 2005. Ground deformation of Nisyros Volcano (Greece) for the period 1995–2002: Results from DInSAR and DGPS observations. *Bulletin of Volcanology* 68, 201–214, doi:10.1007/s00445-005-0004-y.
- Le Pichon, X., Angelier, J., 1979. The Hellenic arc and trench system: a key to the neotectonic evolution of the Eastern Mediterranean area. *Tectonophysics* 60, 1–42.
- Limburg, E.M., Varekamp, J.C., 1991. Young pumice deposits on Nisyros, Greece. *Bulletin of Volcanology* 54, 68–77.
- Liritsis, I., Michael, C., Galloway, R., 1996. A significant Aegean volcanic eruption during the Second Millennium B.C. revealed by thermoluminescence dating. *Geoarchaeology: An International Journal* 11 (4), 361–371.
- Marini, L., Principe, C., Chiodini, G., Cioni, R., Fytikas, M., Marinelli, G., 1993. Hydrothermal eruptions of Nisyros (Dodecanese, Greece). Past events and present hazard. *Journal of Volcanology and Geothermal Research* 56, 71–94.
- Martelli, A., 1917. Il gruppo eruttivo di Nisiro nel Mare Egeo. *Memorie della Societa Italiano della Scienze detta dei XL Serie 3a T. XX*.
- Mc Kenzie, D.P., 1970. Plate tectonics of the Mediterranean region. *Nature* 226, 239–243.
- Nomikou, P., 2003. Santorini and Nisyros: Similarities and differences between the two calderas of the modern Aegean Volcanic Arc. In: *Human Records of Recent Geological Evolution in the Mediterranean Basin Historical and Archeological Evidence, Santorini, 22–25 October 2003 CIESM Workshop Monographs No. 24*.
- Nomikou, P., 2004. Geodynamic of Dodecanese islands: Kos and Nisyros volcanic field. PhD Thesis. Department of Geology, University of Athens.
- Nomikou P., Papanikolaou D., Alexandri S., Ballas D., (2004): New insights on the Kos–Nisyros volcanic field from the morphotectonic analysis of the swath bathymetric map. *Rapp. Comm. Int. Mer. Medit.* 37, 60.
- Nomikou, P., Papanikolaou, D., Lagios, E., 1999. Seismic and volcanic hazard in Nisyros, based on neotectonic analysis and G.P.S. measurements. *E.U.G.10, Strasbourg. J. Conf. Abstr.* 4, 547–548.
- Nomikou P. and Papanikolaou D. (2010): A comparative morphological study of the Kos-Nisyros-Tilos volcanosedimentary basins. *Bull. Geol. Soc. of Greece, Vol. XLIII/1*, 464-474.
- Nomikou P. & Papanikolaou D., 2010. The Active Mandraki Fault Zone of Nisyros Volcano based on onshore and offshore data. *Mar. Geoph. Res.*, in press.

-
- Nomikou P. and Papanikolaou D. (2010): The morphotectonic structure of Kos-Nisyros-Tilos volcanic area based on onshore and offshore data. XIX Congress of the Carpathian-Balkan Geological Association Thessaloniki, Greece, 23-26 September 2010 (Proceedings, in press).
- Papadopoulos, G.A., Sachpazi, M., Panopoulou, G., Stavrakakis, G., 1998. The volcanoseismic crisis of 1996–97 in Nisyros, SE Aegean Sea, Greece. *TerraNova* 10, 151–154
- Papanikolaou, D., 1993. Geotectonic evolution of the Aegean. *Bulletin of the Geological Society of Greece* 28 (1), 33–48.
- Papanikolaou, D., Lekkas, E.L., Sakelariou, D., 1991. Volcanic stratigraphy and evolution of the Nisyros volcano. *Bulletin of the Geological Society of Greece* 25, 405–419.
- Papanikolaou D. & Nomikou P. (2001): Tectonic structure and volcanic centres at the eastern edge of the Aegean Volcanic Arc around Nisyros island. *Bull. Geol. Soc. of Greece*, Vol. XXXIV/1, 289–296.
- Pavlakakis, P., Lykoussis, V., Papanikolaou, D., Chronis, G., 1990. Discovery of a new submarine volcano in the western Saronic Gulf: The Paphsanias Volcano. *Bulletin of the Geological Society of Greece* 24, 59–70.
- Perissoratis, C. 1995. The Santorini volcanic complex and its relation to the stratigraphy and structure of the Aegean arc, Greece, *Marine Geology*, 128, 37–58.
- Sachpazi, M., Kontoes, Ch., Voulgaris, N., Laigle, M., Vougioukalakis, G., Olga Sikioti, G., Stavrakakis, G., Baskoutas, J., Kalogeras, J., Lepine, J.C.I., 2002. Seismological and SAR signature of unrest at Nisyros caldera, Greece. *Journal of Volcanology and Geothermal Research* 116, 19–33.
- Stiros, S., Pirazzoli, P., Fontugne, M., Arnold, M., Vougioukalakis, G., Late-Holocene coastal uplift in the Nisyros volcano (SE Aegean Sea): Evidence for a new phase of slow intrusive activity. *Progress in Volcanology*, 6, 217–225, 2005
- Tibaldi, A., Pasquare, F.A., Papanikolaou, D., Nomikou, P., 2008. Tectonics of Nisyros Island, Greece, by field and offshore data, and analogue modeling. *Journal of Structural Geology* 30 (2008) 1489–1506
- Vanderkluysen, L., Volentik, A.C.M., Principe, C., Hunziker, J.C., Hernandez, J., 2005. Nisyros' volcanic evolution: the growth of a strato-volcano. In: Hunziker, J.C., Marini, L. (Eds.), *The Geology Geochemistry and Evolution of Nisyros Volcano (Greece) Implications for the Volcanic Hazards*. *Memoires de Geologie (Lausanne)*, 44, pp. 100–106.
- Volentik, A., Vanderkluysen, L., Principe, C., Hunziker, J.C., 2005. Stratigraphy of Nisyros volcano (Greece). In: Hunziker, J.C., Marini, L. (Eds.), *The Geology, Geochemistry and Evolution of Nisyros Volcano (Greece). Implications for the Volcanic Hazards*. *Memoires de Geologie (Lausanne)*, 44, pp. 26–67. ISSN 1015-3578.
- Vougioukalakis, G., 1993. Volcanic stratigraphy and evolution of Nisyros island. *Bulletin of the Geological Society of Greece* 28, 239–258.
- <http://www.nisyros.gr>: Official website of Nisyros Municipality.