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# THE RELIEF GENERATION OF THASOS AND THE FIRST ATTEMPT OF FISSION-TRACK DATING IN NORTHERN GREECE

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## ABSTRACT

Geomorphological analysis on the island of Thasos has revealed a sequence of five steplike arranged peneplains (relief generations). Because of distinct relief features like inselbergs, planation surfaces, karst cones, deep chemical weathering horizons, etc. a specific climatically controlled paleo-ecological environment during the time of relief development is obvious. The relative age of relief development can be reconstructed because of dated plutonic intrusions and covering pliocene sediments. By using the apatite fission-track method, an indicator of the age of relief development exists.

## INTRODUCTION

Starting in 1987, several periods of fieldwork have been carried out to explain the geomorphological development of the island of Thasos. The present relief situation exhibits relief features like planation surfaces (karstic, non karstic; pediments) as well as local relief items like inselbergs and karst cones. Together with paleosoils, stratigraphically connected with certain morphological relief features, a specific paleo-ecological setting is testified (cf. BÜDEL 1959, 1981; RIEDL 1977, 1981).

## GEOTECTONIC SITUATION

Situated at the southern end of the Rila-Rhodope Massif (KRONBERG, MEYER and PILGER 1970, p. 140ff) Thasos is bordered by major faults (e.g. LYBERIS 1984, SOKUTIS et al. 1993, PAVLIDES et al. 1990). Between Thasos and Kavala the maximum depth of the tectonic graben is close to 6.000 m (POLLAK 1979, p. 1004). Thasos itself represents a tectonic horst.

The tectonic lineaments of the island (cf. WEINGARTNER 1991, map 2) reveal 4 main directions: NW-SE, NE-SW, W-E and N-S. They fit into the scheme of main fault-lines in northern Greece (e.g.) DOUTSOS and FERENTINOS 1984, p. 37ff).

Some of the faults show close relations to the directions of valleys (e.g. Kastron Ammos valley) as well as to geomorphological features (e.g. Ypsarion fault-line-scarp).

Especially the northwest and northeast areas show tectonic structures parallel to the adjacent main graben directions.

## THE RELIEF GENERATIONS

The questions of relief generations and paleo planation surfaces have been an important topic of morphological investigations during the last two

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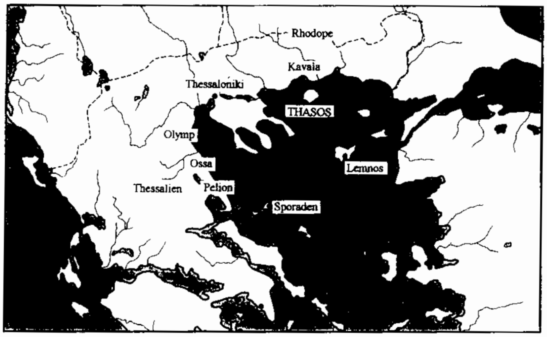


Sketch: H. Weingartner, 1994
Cartography: G. Griesebner

**Fig. 1:** Investigation area - geographical overview

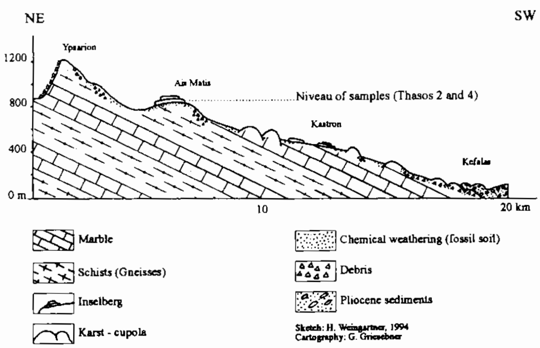


**Fig. 2:** Schematic geomorphological cross section: Ypsarion - Kefalas (Thasos)

decades. It was RIEDL (e.g. 1974, 1976 and 1977), who described and explained various Greek landscapes as a product of climatically controlled relief development. In northern Greece local scientists have found comparable results (e.g. VAVLIAKIS 1981; SOTIRIADIS et al. 1983; PSILOVIKOS 1986 and 1993).

The geomorphological research in Thasos (WEINGARTNER 1989 and 1991) has revealed a steplike arrangement of five major relief generations. These paleo-surfaces have been proved by geomorphological research and by statistical relief analysis, too (WEINGARTNER 1991). Considering the whole island, the surfaces with low inclinatios (below 11°) are concentrated as follows:

| | |
|---|---|
| Niveau I: | >1.180 - 1.020 m |
| Niveau II: | 920 - 820 m |
| Niveau III: | 720 - 580 m |
| Niveau IV: | 320 -160 m |
| Niveau V: | <160 m |

Angles up to 11° and more are described as being still characteristic for the basic weathering front of peneplains (cf. BREMER 1971, p. 168;, RIEDL 1982, p. 205 and 226).

But because of the different tectonic influence in various parts of the island, the above mentioned distribution of low angle surfaces is very general.

In the case of Thasos the distribution of surfaces below 11° have been determined for the morphological homogenious southern region surrounded by the triangle Ais-Matis ridge, Ypsarion and Trikorfon.

For this area the following niveaus could be found:

Niveau I (>1.000 m):

This niveau is represented by the Ypsarion Massif. Main morphological features are remnants of mechanical weathering (debris), tors, karst cones (Prof. Ilias, 1.106 m) and a significant SW-NE-contrast (fault-line-scarp).

Niveau II (800 m):

The existence of this paleosurface is evident from the Ais Matis (809 m) in the southwest as far as Trikorfon (810 m) in the southeast. Into the slightly towards southwest dipping strata, marginal planations are developed in the same altitude, too. The morphology of this system is further characterized by shield inselbergs, a generally undulating relief and remnants of chemical bedrock disintegration.

Niveau III (400 - 600 m):

This paleosurface is generally dipping 2° towards south. A main remnant of this niveau is the central karstic plain of Kastron. East of Theologos the planation surface is developed upon schists and gneisses. Within this niveau remnants of karst plains, karst cones, inselbergs, corestones, as well as deep fossil weathering horizons, are very common.

Niveau IV (300 m):

The main area of this niveau is bound to the south of Thasos (Mandaludi - Trapezia). In the southwestern part of the island this niveau is represented by valley pediments (e.g. lower Kastron Ammos valley). The morphological attributes are similar to these of niveau III, but there is a very clear accent of karst planation, karst cupolas and "woolsack-weathering" upon marbles.

Niveau V (<100 m):

Close to Niveau IV ridges and inselberg-relief follow towards the south (e.g. Palatia, 60 m; Kokkoras, 90 m). Relict red paleosoils are common and authochtoneous chemical weathering horizons appear (WEINGARTNER 1992, p. 425). This youngest niveau is bordered by marginal pediments that represent the change of planation surface development towards linear erosion.

**DATING OF THE PALEOSURBACES**

The planation surfaces of the Rila-Rhodope have been given miocene age as they are developed upon miocene granites (PSILOVIKOS 1993). Already VAVLIAKIS puts the lower Menikion-pene-plain into the Middle Pliocene (1981, p. 31f).

Concerning the stratigraphical position of the peneplains of Thasos the age of the neighbouring Kavala-plutonite has to be taken into account. After KOKKINAKIS (1980), the cooling age of the plutonite is 14 respectively 19 Ma. Because of the close neighbourhood of Thasos and the pluton on the mainland a corresponding age of peneplain development may be assumed. Before the development of the peneplain, a remarkable piece of upper-crust, originally covering the plutonite had to be eroded. The depth of the intrusion can be estimated at least 10 km (cf. WINKLER 1967, SOKUTIS 1993).

As the lowest relief generation of Thasos (niveau V) is supposed to be covered with sediments of the Lower Pliocene (LYBERIS and SAUVAGE 1985, p. 587) the maximum timespan of relief development is concentrated to the Upper Miocene.

Because of the known cooling age (14 Ma) and the probable beginning of pliocene sedimentation (5.4 Ma), the minimum time for erosion can be estimated 8.6 Ma. Thus a medium erosional rate of 1.2 mm/a is plausible.

Beside the possibilities of relatively estimating the age of paleosurfaces further methods of dating do exist. In this connection apatite fission-track dating has been a very useful method and well known for many years (cf. WAGNER 1968).

Through spontaneous fission of the nuclide $^{238}U$ a damage zone is formed in insulating solids (crystals and glasses). There is a proportion between the number of fission-tracks and uranium concentration in the mineral as well as to the time which has elapsed since closing of the uranium fission-track system (cf. WAGNER 1968; WAGNER and VAN DEN HAUTE 1992).

Apatite fission-track dating was used for example, to investigate the post-orogenic uplift of the Alps (HEJL and WAGNER, 1991). To determine the influence of tectonism on landform development, the method was applied in the crystalline basement of northeastern Bavaria (BISCHOFF, 1993; BISCHOFF, SEMMEL and WAGNER, 1993).

Until now, only few fission-track data were reported from Greece (ALTHERR et al., 1979; ALTHERR et al., 1982; SEWARD et al., 1980). No fission-track data concerning the northern Aegean Sea and the adjacent coastal areas have been published yet.

In the course of our investigation, the apatites of two samples from Thasos were dated by the grain population method: a phyllitic schist from Ais-Matis ridge (Thasos 2) and an amphibolite from Trikorfon (Thasos 4). From the geomorphological point of view both samples belong to Niveau II (800 m).

Apatite was enriched by the flotation procedure described by HEJL and NEY (1994). Afterwards, the apatite concentrates were purified by conventional magnetic and heavy liquid separation. One part of each sample was heated at 550°C for 24 h and subsequently irradiated in the thermal column of ASTRA reactor (Seibersdorf, Austria). According to VAN DEN HAUTE et al. (1988), the thermal neutron fluence was measured by γ-spectrometry of simultaneously irradiated Co-monitors. The apatite populations (natural and irradiated0 were embedded separately in epoxy resin, polished and etched in 5 % $HNO_3$ for 60s at 20°C. An Olympus BHT microscope with a total magnification of 1250 x (oil immersion, transmitted light) was used for track counting. The results are reported in Table 1 which follows the recommendation of the I.U.G.S. Subcommission on Geochronology (HURFORD, 1990 a and b).

For the samples SASP 44 (Thasos 20 and SASP 46 (Thasos 4) apatite fission-track ages of 8.25 + 1.04 Ma and 8.24 + 0.81 Ma were determined. Thus the geomorphological interpretation putting both rather distant areas into the same niveau and relief generation has been testified.

Due to the low natural track densities of both samples no lengths of full confined spontaneous tracks could be measured. Despite this lack of information, the measured ages can be considered as cooling ages, because an important post-Miocene reburial of the present 800 m level is very unlikely.

Concerning the age of surface development we must take into account that both areas crossed the 100°C cooling temperature at the same time (cf. WAGNER and VAN DEN HAUTE 1992). Using a probable medium geothermic gradient of 30°/ 1.000 m and a possible medium paleosurface temperature (Upper Miocene/ Pliocene) of 16°C 2.800 m of crust had to be eroded before the development of the recent visible paleo surface. According to the medium erosinal rate of 1.2 mm/a ate least 2.33 Ma have been necessary for the erosion.

Thus the method proves that an older age than 8 Ma for the development of Niveau II can be excluded and according to the erosional rate, as well as to the thickness of the crust which had to be eroded, a probable age of planation surface development during the uppermost Miocene/Pliocene seems probable.

As on Thasos three lower (younger) relief generations than that of the 800 m-niveau were developed (according to the piedmont model - SPREITZER 1951) a

**Table 1:** Measured apatite fission-track data

| Sample | number of grains $n_s/n_i$ | spontaneous $N_s$ | spontaneous $\rho_s$ [$10^5$ cm$^2$] | Induced $N_i$ | Induced $\rho_i$ [$10^5$ cm$^2$] | rel.error of $\rho_s/\rho_i$ [%] | Neutron fluence [$10^{14}$cm$^{-2}$] | FT age ± 1σ [Ma] |
|---|---|---|---|---|---|---|---|---|
| SASP 44 (Thasos 2) | 400/300 | 257 | 0.4016 | 1161 | 2.4188 | 12.4 | 10 | 8.25±1.04 |
| SASP 46 (Thasos 4) | 600/300 | 204 | 0.0694 | 615 | 0.4184 | 9.5 | 10 | 8.24±0.81 |

$N_S$ $N_I$: numbers of spontaneous and induced tracks counted
$\rho_s$ $\rho_i$: areal track densities of spontaneous and induced tracks.
The following constants were used for the age calculation:
$\lambda_f$ = Decay constant for spontaneous fission of $^{238}U = 8.46 \cdot 10^{-17} a^{-1}$
$\lambda_d$ = total decay constant of $^{238}U = 1.55125 \cdot 10^{-10} a^{-1}$
$\sigma$ = thermal neutron cross section of $^{235}U = 580.2 \cdot 10^{-24} cm^2$
$I$ = isotopic ratio $^{235}U/^{238}U = 7.2527 \cdot 10^{-3}$

development of the lower systems during Lower and Middle Pliocene is possible.

A development of the planation surfaces later than the accumulation of the pliocene sediments together with the imagination of an original sediment cover upon the whole island (cf. PETEREK 1992, Fig. 135) is more than questionable, because there is no evidence of deep chemical weathering upon the pliocene sediments and with the exception of the marginal southern areas no further remnants of the postulated sediment cover have been found (WEINGARTNER 1993, p. 224).

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