Δελτίο Ελληνικής Γεωλογικής Εταιρείας τομ. XXV/4, 67-82, 1991
Πρακτικά 5ου Επιστημονικού Συνεδρίου, Θεσσαλονίκη, Μάϊος 1990

Bulletin of the Geological Society of Greece vol. XXV/4, 67-82, 1991
Proceedings of the 5th Congress, Thessaloniki, May 1990

LANDFORMS AND PROCESSES ASSOCIATED WITH THE EXHUMATION OF THE PLUTONIC BASAL SURFACE IN THE AREA OF THE AEGEAN ARCHIPELAGO

H. Riedl[1]

Contents:

ABSTRACT

In the presented paper the author gives a survey of the main processes and dominant landforms that are associated with the stripping of the plutonic basal surface from deeply weathered paleosol covers. In the last decade several Greek scientists, above all A. Psilovikos (1981, 1982), L. Sotiriadis (1981) and E. G. Vavliakis (1981), have investigated the relict peneplains whose various components were subject to considerable remolding. All these landforms developed primarily cryptogenically under autochthonous, chemically weathered material. Exhumation took place in the course of the Oldest, Older and Younger Pleistocene when these covers were easily removed. Recent times represent a period of rigorous modification of this once subcutaneous relief. The analysis is based on extensive, detailed fieldwork on the islands of Seriphos, Mykonos, Ikaria, and Naxos and includes comparisons with Siphnos, Syros, and Samos, though igneous rocks either do not occur there or are of no significance.

1. Introduction

Paleoecologically determined landforms are widely distributed on the Aegean archipelago, and the elements of peneplains of various ages and of altitudes represent dominant features of all island reliefs even though the geologic structures vary. In spite of that, the Younger Tertiary ancient landforms in the areas with plutonic bedrock display special characteristics. The deep chemical weathering, which was promoted by lithology and directed by climato-morphological

1 Institute of Geography, University of Salzburg,
Hellbrunnerstraße 34, A-5020 Salzburg

processes, may be regarded as the main reason for the predominance of the basal surface as well as for the characteristic properties of the associated exhumation processes. Intrusive rocks and the groups of forms related to them are found on Tinos, where a larger monzogranite body and a smaller granite one intruded in a late or posttectonic period. According to St. Dürr (1986, p. 132), the K/Ar age amounts to approximately 15 m.a. Geomorphologic investigations concentrated on Seriphos (Riedl, H., 1986), whose southeastern part is marked by a granodiorite which cooled only 8 - 9 m.a. ago (Dürr, St., 1986, p. 133). On Naxos (Riedl, H., 1982) a type I-granite intruded after the crust was uplifted. This pluton occupies the western part of the island. According to St. Dürr (1986, p. 138) and Altherr et al. (1982), its age may be estimated to at least 11,1 ± 0,7 m.a. Systems of landforms similar to those on the Miocene granodiorites of Naxos are also observed on older, Late Oligocene migmatites that developed from a probably pre-alpide basement. Further weathering fronts are described on the islands of Delos and Mykonos (Riedl, H., 1980), where gneissic granites prevail that in part exhibit strong deformations. The intrusion attains an age of at least 14,7 m.a. (Dürr, St., 1986, p. 142; Altherr, 1982). Studies were also carried out on Ikaria (Riedl, H., 1989) including the distinctly developed basal surfaces and the associated forms of exhumation; on W-Ikaria these landforms are not only developed on leucobiotite granites of type I, which appear as "gneissoid granites" with an age of about 25 m.a. (Dürr, St., 1986, p. 176). They also occur on a body of two-mica granites that intruded approximately 18 m.a ago.

The groups of landforms on plutonic bedrock differ from the systems of piedmont benchlands and peneplains as well as from the structurally determined hogbacks that were investigated in the area of the schist cover of the Attic-Cycladic complex on Siphnos (Riedl, H., 1983), Syros (Riedl, H. 1989), and on Samos (Riedl, H., 1989). Due to the lithologic properties of the schist and marble complexes, the basal surfaces - though existent - show entirely different morphological features in comparison with those on granites, granodiorites, gneissoid granites and similar rock types.

2. Basal Surfaces and Their Primary Habit

All basal surfaces (Büdel, J. 1959, 1968) under investigation turned out to be groups of landforms consisting of azonal relict inselbergs and dome mountains (Wilhelmy, H., 1959, p. 66 ff) with residual "haldenhänge" (wash slopes) and a variety of shallow valleys lying in-between. Two reasons are responsible for the dominant woolsack-type boulder weathering: On the one hand, it was determined by paleoecological factors resulting from a tropical, seasonally humid climate; on the other hand, the well-joined igneous rocks are susceptible to this kind of weathering. Due to differentiated penetration depths, the very intense chemical weathering with its typical matadero horizon (Kubiena, W., 1955, 1956) generated an irregularly shaped paleorelief. Due to the numerous inselbergs, the terrain shows a great variation in elevation. The climato-morphological heritage is not only manifested by these landforms, but also by paleoplastosols occurring as residual brown and red soils and as kaolinizations which were promoted particularly by the inhomogenous structure of igneous rocks (strongly varying sizes of the feldspars).

Considering the fact that the Mesohellenic molasse was overthrust in pre-Messinian time and that the planation surfaces cut all the nappes, the primary genetic age of the basal surface (Riedl, H., 1984, p. 160) may be estimated as Upper Miocene-Lower Pliocene (Riedl, H., 1984, p. 160). Even before this stage, however, an intra-Torton "primärrumpf ("primary peneplain"; Riedl, H., 1982, p. 18f) developed, most parts of which are encrusted by molasse. Only on Samos and Ikaria (Riedl,

GEOMORPHOLOGIC MAP OF THE AMPELOS MOUNTAINS AND THE BASIN OF MYTILINI (SAMOS)

- Level of Karvuni (1000 - 1153 m)
- Level of Kochili (880 - 920 m)
- Level of Petaluda (720 - 780 m)
- Margin of the mountains (pediment - glacis)
- Basin of Mytilini (470 - 600 m)
- Corridor of Pirgos (400 - 650 m)
- Glacis (300 - 400 m)
- Glacis terrace (200 - 230 m)
- Glacis terrace (120 m)
- Steep paraclinal slopes on Neogene
- Ridge
- Rounded interfluve, strongly dissected ridge, convex form
- Alluvial cone, alluvial fan
- Scarp on bedrock bordering the Neogene basin
- Scarps dissected by funnel shaped depressions
- Fault scarp with landslide accumulations
- Younger Pleistocene talus slopes and alluvial cones
- Area of subsequent erosion
- Shallow valley with gently sloping concave sides
- Shallow valley with gently sloping concave sides undercut by karst corrosion
- Flat-floored, V shaped valley, coastal plain
- V-shaped valley
- Small epigenetic gorge

1989, p. 190) these "primärrümpfe" originate from the Upper Serravallium.

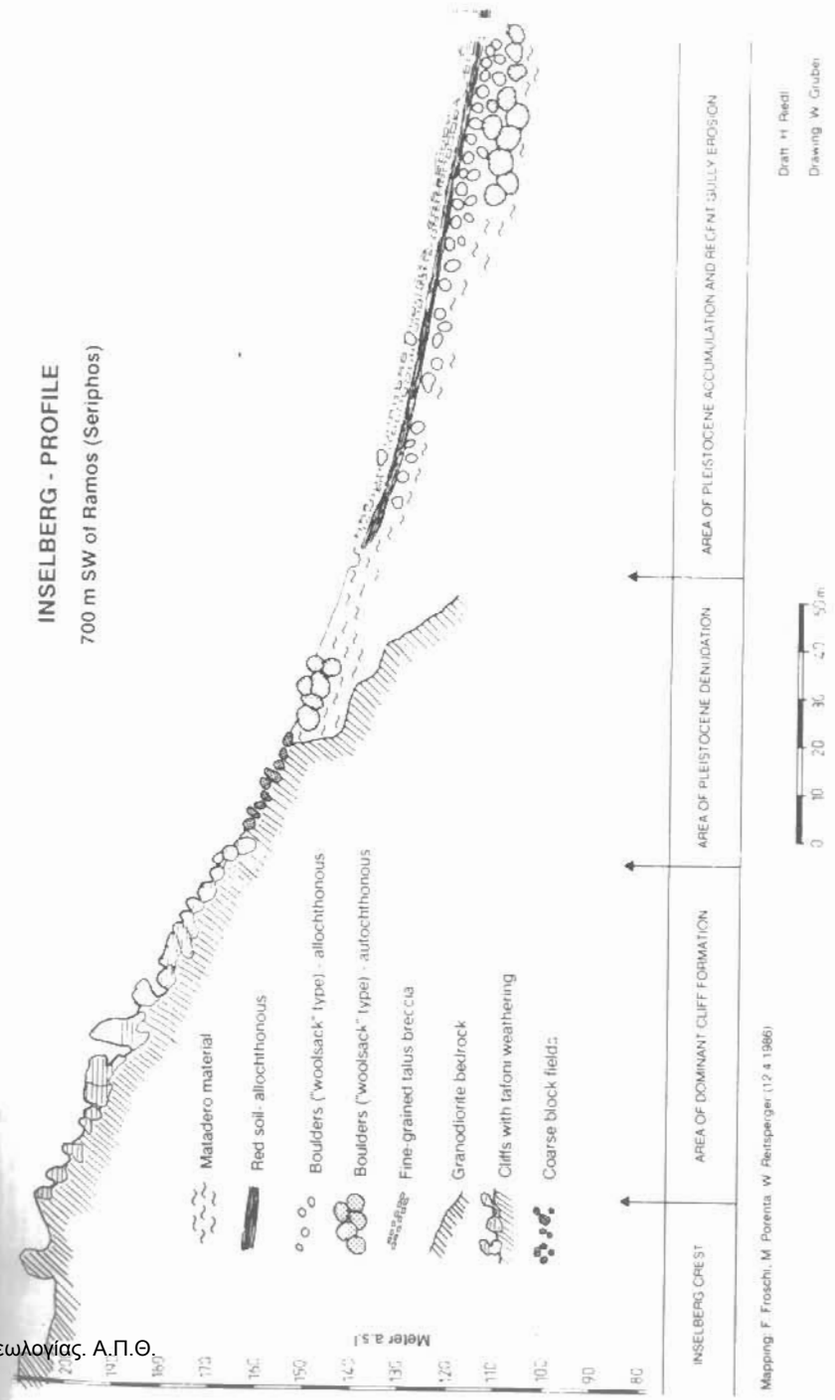
3. Periglacial and Convergently Periglacial Transformations of the Basal Surface

In the course of their exhumation from thick covers of chemically weathered material, most primary genetic elements of the basal surfaces were subject to morphodynamic modifications and remolding. The Upper Pliocene and above all the Quaternary may be regarded as the main periods when the subcutaneous bedrock of the basal surface was exhumed.

3.1. Asymmetric Inselbergs

As investigations on Seriphos have shown (Riedl, H., 1986, p. 63), this type of landform may serve as a good example for the more recent trends of remodelling. The tops of the shield inselbergs and the basal slopes are connected by gentle slopes with inclinations of 8° that are composed of veneers of small-sized detritus (with longitudinal axes of 1 - 4 cm). These blankets reveal an average thickness of 0,5 - 0,7 m and mask the matadero-weathered granodiorite. The upper end of such younger Pleistocene debris covers, today consolidated, coincides with a sharp break of the inselberg slope and leads to a steepening of the basal slopes. These footslopes are characterized by inclinations of 18° and are developed in matadero. Only the summit areas of the 20 to 60 m high inselbergs convey fresh rock of convex form. Whaleback-shaped, they asymmetrically slope down to parts that show declivities of 8 - 10°. The matadero horizons (Riedl, H., 1986, p. 85) represent the product of Miocene-Lower Pliocene weathering processes. They can be cut with a knife and constitute the C-horizon of tropical red soils. Common property of the various types of matadero are clayey parts that reach down to great depths in a joint-like pattern. The soil type may be classified as clay loam, whose colour value ranges from 2.5 YR 4/8 to 7.5 YR 5/6. These parts are characterized by a high plasticity and alternate with undulating layers that show a colour value of 7.5 YR 5/8. Compared with this old pre-Pleistocene type of weathering, the small-sized detritus of granodiorite rock marks a distinct contrast. These sheets of small-sized detritus occur at an average altitude of 600 m and display some common features, such as the homogenous size of the material, persistent sharp edges and the modifications induced by meridional brown soils. The detritus is embedded in a matrix of weakly loamy sand. A close relationship exists between the colour values of the matrix and those of the matadero horizons.

In the Younger Pleistocene the remnants of the Younger Tertiary plastosols - at that time still more frequent and deeper - served as ideal slides for the detritus even on the gently inclined "rampenhänge". On the one side, the B_v and B_v/C_m horizons of the relict soils were removed in the course of debris transport, on the other side the remnants of the paleosols were truncated to a large extent. In altitudes above 600 m (Seriphos, Ikaria, Samos) these movements predominantly took place on gentle slopes with inclinations below 10°, thus modifying them at the same time. This preference may be explained by the phenomenon of needle ice and frost action processes. Short rill transport by running water over distances of a few hundred metres did not have any essential effect on the character of the detrital sediments. For the summit areas of the basal surfaces on Seriphos we may assume Younger Pleistocene mean winter temperatures of 1 - 2°C and winterly diurnal fluctuations of 2.5°C. These values would just be sufficient enough for the development of needle ice. On Ikaria, however, where the basal surface is situated at an altitude of about 1.000 m, needle ice action was in full progress.



3.1. Inselbergs with Wall-like Scarps

Similar to Naxos and Mykonos, inselbergs with wall-like scarps represent essential elements of the basal surface on Seriphos as well as on Ikaria. Their present-day form may be considered as yet another example of the modification of the Younger Tertiary relief.

3.2.1. The **top of the inselberg** often appears sharp-crested and is crowned by sharp-edged tors.

3.2.2. An abrupt knickpoint separates the summit from the **area of dominant cliff formation** which reveals slope angles of 30 - 35°, in some cases up to 43°. Distributed on this convex steep relief, we often find giant "woolsack"-type boulders, which may be up to 15 m long. The cliff area shows the attributes of a primary genetic residual talus. Its lower margin is marked by a concave break of slope.

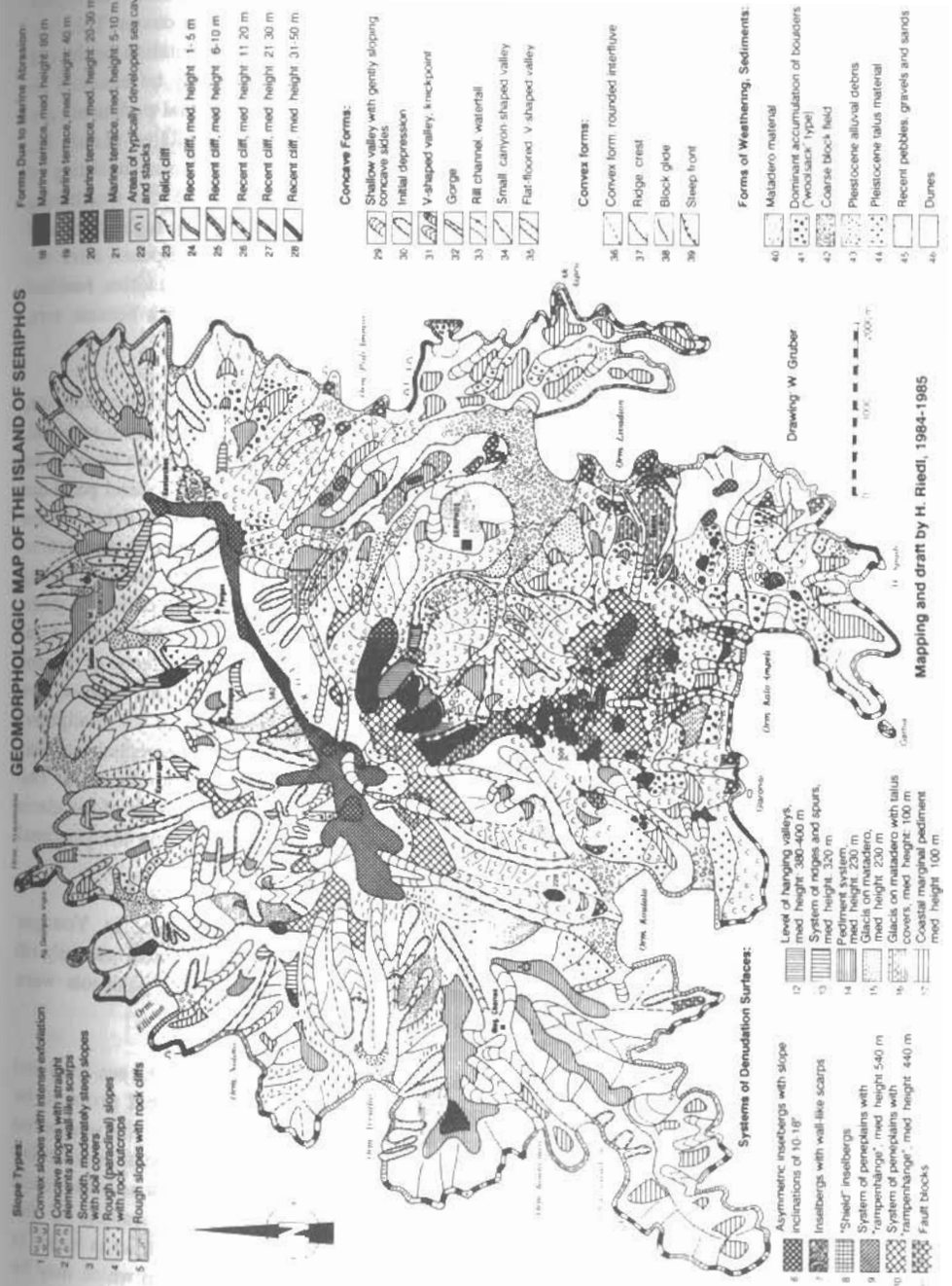
3.2.3. This break forms the transition between the cliff area and the **area of Pleistocene denudation**. The concave slope profiles are characterized by inclinations of only 15 - 25°. The matadero contains autochthonous medium- to small-sized boulders ("woolsack" type). The associated overlaying red soils have been removed down to the lowest parts of the B_{vrel}/C_m horizons, which is the reason for the great hiatus between the matadero and the topping meridional brown soils.

3.2.4. The succeeding **area of Pleistocene accumulation** coincides with the main area of recent sheet erosion. These gently concave basal slopes reveal inclinations of 8 - 10°. Instead of autochthonous boulders, allochthonous ones prevail which disappear below small-sized detritus towards the end of the slope profile. The Pleistocene sediments of this part of slope are 5 - 8 m deep and represent the correlate materials of the area of Pleistocene inselberg denudation. In a depth of 3,5 - 2,0 m the dislocated boulders are covered by allochthonous redbrown relict soils, whose content of coarse grains amounts to 60 - 70 %. Due to their densely packed structure, these soils appear as extreme pseudogleys, which may be interpreted as a result of in-situ processes in the Younger Pleistocene.

The arrangement of the various slope elements and the structure of the Quaternary sediments imply that the steep-walled inselbergs of the Younger Tertiary basal surface were affected by extensive sheetwash. Especially in Younger Pleistocene times this process had a strong impact on the rampenhänge (Lous, H., Fischer, K., 1979, p. 184) that are developed in matadero. Forming aprons, the correlate debris accumulations extended upslope and began to bury the steep inselberg sides. Thus landforms developed convergent to those of arid-semiarid climates, yet with a genetically entirely different background. The convex-concave profiles typical of the higher inselbergs of the basal surface as well as the aprons of sedimentary covers on the originally less inclined "rampenhänge" may thus be interpreted as results of Pleistocene modifications.

3.3. Marginal landforms of the Mountains (Pediment - Glacis)

The landforms of pediments and glacis are of double significance for the exhumation of the weathering front.



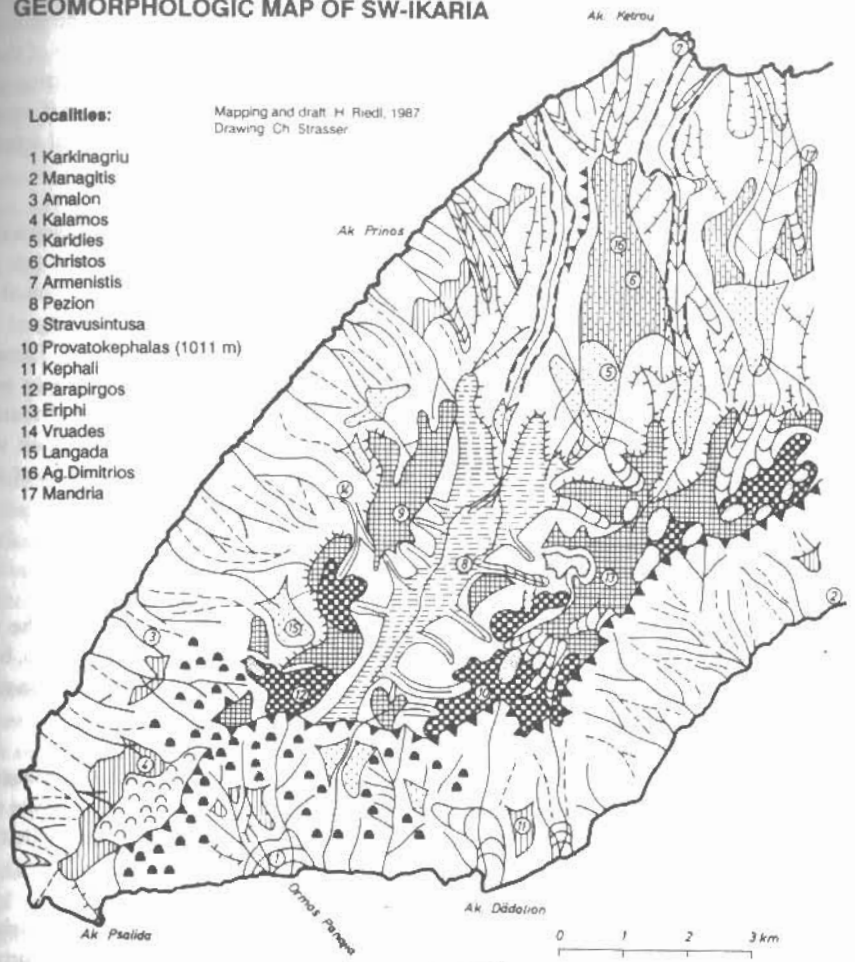
3.3.1. On most of the Cycladic islands we may distinguish an older generation of pediments that appears as **coastal marginal pediments** (Riedl, H., 1984, p. 168) at a present average height of 100 m. The few glacis cut the Upper Pliocene. Pediments and glacis extend across all recent bays and thus prove to be older than the present morphology of the rias and cala coasts. This fact implies that the present islands emerged only after this continental stage of pedimentation on the old basal surface of Youngest Miocene age. The period of pediment formation may be assumed as Plio/Pleistocene lasting perhaps until Older Pleistocene times. The coastal marginal pediments are linked to the pronounced slope concavities of the weathering front and to the "kehltäler" (Louis, H., 1964), respectively, which deeply dissect the basal surface. This assemblage of forms consisting of pediment, "kehltal" and slope concavities represents the main route along which the weathering products were transported in Oldest and Older Pleistocene times. In this period the highest rates of exhumation were acchieved. Considerable parts of the inselberg relief were then exposed after the erosion of the mantling products of chemical weathering. Due to these stripping activities, residual accumulations of boulders were uncovered, and the remaining solid mass of bedrock became tors, bell-shaped or helm-shaped mountains.

3.3.2. **Glacis on matadero with debris covers**: Apart from the coastal marginal pediments, the plutonic basal relief is marked by characteristic glacis developed on the soft matadero material. Prototypical examples may be distinguished on Ikaria and Seriphos. On Ikaria the glacis begin at an altitude of 200 m at the foot of triangular-shaped slopes formed in matadero. Their distal parts cut the almost vertically dipping marine conglomerates of Pliocene age. The thickness of debris at the distal part of the glacis, which borders the recent cliffs south of the Xilosirtis granite body, amounts to 15 - 20 m. Structures similar to those of mudflows prevail. The alluvial debris show a strong conformity to those on the Cyclades of Younger Pleistocene age. Beyond the recent cliffs, the glacis and their debris covers extend below the sea-level. Conversely to the ancient character of the distal parts of the glacis, the proximal ones as well as the pediments show the effects of recent morphodynamic processes. The triangular-shaped rear slopes of the pediments, for instance, are subject to strong sheet erosion which is responsible for the active frontal retreat of the triangular-shaped slopes in the soft matadero of the basal surface. It must be considered an essential fact that parts of these landforms are destroyed nowadays, while others undergo further development. The distal parts of the glacis accumulations, for example, reveal a recent ridge-like dissection of the glacis and of their covers of debris down to the matadero unit, whereas at the same time the proximal pediplains, the debris-deficient pediments, are still in progress.

The rate of exhumation acchieved by this process was considerable. In Younger Pleistocene times, when the blankets of alluvial debris and the pediplains were formed, not only rill channels cut deeply into the solid bedrock. Furthermore, the pre-Pleistocene paleosols were rigorously eroded from the triangular-shaped slopes.

The alluvial debris (Kelletat, D., 1975), however, which extend down to the sea-level and beyond, must not be regarded as the result of periglacial frost action processes, but prove to be phenomena convergent to them. On Seriphos the sediments of the glacis that cut the weathered granodiorite in a discordant manner represent a medley of debris and various allochthonous relict soils of the Younger Tertiary type. We may distinguish remnants of red soils as well as brown clays and loams whose autochthonous remnants are exposed on the "rampenhang" systems of the peneplains. The allochthonous soils contain grus and small-sized waste and are embedded as lenses in the layers of coarse debris. The entire sediment reflects a wild, unsorted deposition which may be

GEOMORPHOLOGIC MAP OF SW-IKARIA



Mapping and draft: H. Riedl, 1987
Drawing: Ch. Strasser

Localities:

1 Karkinagriu
2 Managitis
3 Amalon
4 Kalamos
5 Karidies
6 Christos
7 Armenistis
8 Pezion
9 Stravusintusa
10 Provatokephalas (1011 m)
11 Kephali
12 Parapirgos
13 Eriphi
14 Vruades
15 Langada
16 Ag. Dimitrios
17 Mandria

- Area of exhumed remnants of castellated rocks and inselbergs
- Level of Provatokephalas (900 - 1011 m)
- Level of Stravusintusa (740 - 850 m)
- Level of Pezital (720-810)
- Level of Karidies (400 - 600 m)
- Level of Karidies: ridge type
- Level of Kephali (285 - 350 m)
- Bell-shaped mountains
- Slopes dominated by boulders, "kernsprung" and taloni weathering
- Gorge
- V-shaped valley
- Flat-floored incised valley, small flat-floored valley
- Shallow valley with gently sloping concave sides
- Gullies on gentle slopes
- Gullies on steep slopes
- Crest, ridge
- Sharp ridge, convex form
- Sharp break of slope
- Break of slope

associated with mudflow activities. The detritus is not rounded, and the granodiorite fragments - most of them strongly weathered - have sizes of 3 - 5 cm or 20 - 30 cm. Quite frequently the sediments are cemented together like breccia so that small resistant steps may develop in the course of the erosive dissection of the glacis. The whole situation demonstrates that no periglacial frost action processes could be involved in the eu-Mediterranean low-lying zone of the Aegean Archipelago if we assume a mean temperature of 4 - 5°C for the Würmian maritime winter and a mean diurnal amplitude of about 2.0 - 2.5°C.

Compared with the present climatic characteristics on Seriphos, the development of the glacis and the deposition of the sediment covers with thicknesses of only 0.8 - 2.0 m imply considerably more humid conditions for the Younger Pleistocene. The type of sediment and the structure of the glacis cutting the bedrock indicate the activity of distributary, divergent channels which in sum caused the planation at the fringes of the basal surface on Seriphos. These leveled surfaces show declivities of 5 - 12°. In connection with these processes, the deeply weathered Younger Tertiary materials, which were produced in the course of ancient peneplain formation, were subject to intense erosion. At the same time, the more resistant backing slopes of the glacis, which are developed on granodiorite bedrock, were undercut by the retreat of the proximal parts of the glacis situated in matadero.

3.4. Breccia, Alluvial Debris and Smooth Slopes ("glatthänge")

The Younger Pleistocene period does not only represent a stage when the marginal exhumation of the basal surface was induced by the development of the glacis in matadero, but it may also be regarded as a phase when the existent depressions were enlarged by the formation of smooth slopes.

3.4.1. Smooth slopes on plutonite basal surfaces are often associated with **concave slopes with straight elements and wall-like scarps**. On Seriphos, for example, this type of slope coincides exactly with the distribution of the granodiorites. It does not occur anymore in terrain that includes bedrock consisting of scapolite,granite, hornblende, and hornfels.

The slope elements are arranged in a typical sequence of great regularity consisting of a scarp, an area of "haldenhang" (wash slope) formation with rock outcrops, and a mighty succession of smoothed mid- and footslope sections. The smoothness of both parts does not originate from erosional processes due to the upward retreat of the wallfoot as in case of the wash slope of the upper section. Their smoothness rather depends on the development of in-situ rock debris. The mid-section and lower parts of this slope type are mantled with scree several meters deep. The sequence of wall - wash slope - smooth slope with debris covers represents a particularly characteristic feature in cases where this type of slope links the margin of the elevated peneplain systems of the basal surface with the lower lying landforms of pediment and glacis. The walls always consist of unweathered, solid igneous rock and show slope angles of 40 - 60°.

3.4.2. The slope debris, partly consolidated, gradually merge into alluvial cones. Layers of red soil with detrital intercalations represent distinct attributes. The colour values of the allochthonous soils dating from Younger Tertiary times amount to 2.5 YR 4/8. This alternation of red soil and debris may be considered a typical feature of Late Würmian alluvial accumulations (Riedl, H., 1981, p. 31). The deposition of mudflow material alternates with stages of dominant sheet erosion

of fine-grained soils and of enforced accumulation of fine-grained material. These variations represent further characteristics of this slope segment. The alluvial debris, which may be defined as the correlate deposits to slope denudation of the basal surfaces, also contain kettle-shaped structures and pocket-like phenomena. If we consider the maritime climate of the mediterranean low-lying zone (generally 0 - 600 m in height), these forms were certainly not produced by a Younger Pleistocene climate that involved frost heaving structures in the region of insular coastal plains. They must be interpreted as phenomena convergent to periglacial ones and may be explained by erosive pothole dynamics and related processes (Riedl, H., 1984, p. 173).

4. The Impact of the Initial Linear Fluvial Erosion

This morphodynamic type (Louis, H., 1985, Louis, H. und Fischer, K., 1979, p. 104) may be described by the fact that apart from the rill-head, both channels and accompanying slope generally share the same inclination.

4.1. The key elements of initial linear fluvial erosion have a great impact on the modification of the plutonic basal surface. Rills are the first forms to develop. In contrast to the major forms responsible for exhumation, rills must be assigned to the processes that induce the recent destruction of the basal surface. Due to the absence of forest covers and the prevailance of phrygana, the rills on igneous rocks may be regarded as guidelines to most effective recent erosion in the zone of Mediterranean heavy rainfalls.

Throughout winter until the end of April the rills represent morphodynamically active zones which are characterized by algae threads. The rills, which are often used by semianually persistent waterfalls, possess no drainage area. Due to headward erosion, however, the rills retreat into the remnants of matadero blankets on the elevated peneplains of the basal surface where the matadero acts as aquifer. The effectivity of the surface runoff is thus prolongated by this capture.

The rills are mostly attributed with convex sides and dissect the Pleistocene slope debris. On Ikaria (Riedl, H., 1989, pp. 203 f.) they are incised into the slopes of the basal surface down to a depth of 100 m. Sometimes they function as recent tributary systems of large relict valleys. The rill slopes generally attain angles of 20° and may exceed this value in association with tors. Boulder streams represent a characteristic feature of the rill channels, particularly of the heads. The distal parts of these deposits are occupied by erosional potholes that are frequently combined with scour marks. Their genesis does not only depend on erosive activities in winter and springtime, but also involves the hydrolytic solvent ability of the residual water that remains in deep potholes until late summer. The longitudinal profile of the rills is often structured by vertical waterfall steps, 5 - 10 m in height, which develop in solid granodiorite (Seriphos), migmatite (Naxos), or gneissoid granite (Mykonos, Ikaria) and whose crests get showered. If such rill channels cross pockets of matadero material, a dendritical system of rain rills will develop that are tributary to the rills.

In sum, the holocene rills contribute not so much to the stripping of the weathered masses, but rather to the degradation of the basal surface itself, thus inducing a rapid destruction of the relief.

4.2. Conversely to the rills, the **initial depressions** (Riedl, H., 1986, p. 81) represent dominant features of the Younger Pleistocene initial linear fluvial erosion. In general, their declivity

ranges between >15 to >35°. These wide-spanned slope concavities often appear as niches of cultivated land and are filled a few metres thick with colluvial red soils mixed with debris.

5. Key Features of Dominant Linear Fluvial Erosion

5.1. The **V-shaped valleys** of the basal surface resemble a characteristic concave form of this erosional type (Louis, H., u. Fischer, K., 1979, p. 103). It must be considered a peculiarity of these valleys that their beginnings are marked by steeply inclined erosional funnels, which are entrenched into the highly elevated peneplain systems of the basal surface. The wide clear span of the section below the erosional funnels as well as the numerous knickpoints in the linear profile of these valleys represent remarkable traits. Considering the abundant potholes in the beds of the streamlets, they may classified as recent concave forms associated with highly intense erosional activities that lead to a deep dissection of the basal surface. The frequent waterfall steps, however, are not an exclusive characteristic of V-shaped valleys. Such sections of marked rapids may also be associated with hanging valley-shaped, shallow valleys with gently sloping concave sides. This valley type betrays a great similarity to the sulas of Surinam as described by Bakker (1957). Therefore we might consider the possibility that after the tectonic break-up (genesis of the islands) had succeeded the continental stage in the Aegean Sea of Plio/Pleistocene and Older Pleistocene times, the V-shaped valleys developed from primary shallow valleys or "kehltäler" of tropical origin (Riedl, H., 1986, p. 82).

5.2. **Flat-floored, V-shaped valleys** generally determine the lower courses of the V-shaped valleys and gorges at the transition to the coastal plains. Sometimes the outcropping igneous rock leave so little space that the turning point from linear to lateral erosion lies beyond the coast line. In that case the clear V-shaped profile (cala coast) is predominant down to the river mouth. Similar to the presumably higher age of the V-shaped valleys, the flat-floored, V-shaped valleys turn out to have existed even before the Younger Pleistocene. Fieldwork (Riedl, H., 1986, p. 90; 1983, pp. 47ff.) revealed that the alluvial debris of Younger Pleistocene age continue below the present torrent bottom. This fact implies that the deposition of the mudflow cones was preceded by an initial valley bottom. Yet the present beds of the torrents are undoubtedly younger than the 1 m high accumulation terraces as they are dissected by the valleys. Before this latest stage of incision, the flat-floored, V-shaped valleys probably served as sediment reservoires in the phase of enforced sheet erosion which covers the period of 5,000 - 3,500 BP, that is the period when the climate on the Aegean Islands turned Mediterranean (Hempel, L., 1982, p. 54). This subrecent stage of accumulation, which includes fine pebbles, gravels and sands (1 m-terrace), may serve as evidence that this was the last period when due to climato-morphological processes the basal surface was subject to large-scale sheet erosion which removed the disintegrated rock parts and the chemically weathered material.

6. Recent Trends of Basal Surface Modelling

6.1. Tafoni Weathering, Exfoliation and Pseudokarst Processes

If we regard the various types of inselbergs, tors and marginal walls as well as the steep reliefs as paragons of the basal surface, these three groups of processes are responsible for the present conformable further development or remolding of the basal surface although most of the chemically weathered material have been denuded and eroded.

6.1.1. In the area of Aegean igneous bedrock typical **tafoni weathering** is found on tors, on inselberg slopes comprising slope cliffs and "woolsack"-type boulders, and in the steep relief of residual slopes, though tafoni may also occur in the schist cover of the Attic-Cycladic complex (Riedl, H., 1981, p. 57). According to the investigations by H. Weingartner on Naxos (1982, pp. 90ff.) and on Thassos (Th. Resch, 1989, pp. 82f.), H. Wilhelmy's theory can hardly account for the genesis of these denudation mechanisms. One of the most significant results of H. Weingartner's studies is the fact that the inner surfaces of the tafoni are not affected by deep weathering (hydrolysis etc.); scaling and granular disintegration prevail. There is no causal connection with resistant rinds. The various sizes of these forms play an important role. Inside smaller tafoni, an independent microclimate can develop more readily. In this case, the fluctuation of a high deficiency of saturation by day and a lower one by night produces the alternation of hydration and dehydration. Yet a considerable influence on the trend of development of the basal surface is exercised by the frequent basal-tafoni. They often occur along pressure-release joints or cooling cracks, but they may also be adjusted to the former slopes in matadero (Riedl, H., 1989, p. 211), which have long been undercut and degraded so that the basal-tafoni become side-tafoni. The basal-tafoni generate the effective destruction of the slope cliffs and woolsack-type boulders. In the course of tafoni-aging and under the present climatic conditions, these boulders (evidencing the Neogene deep weathering) are replaced by sharp-edged fragments of hollowed boulders that constitute the remnants of the once rough terrain of the basal surface. On Ikaria discus-shaped, collapsed tors of gneissoid granite bedrock serve as impressive demonstrations of the final stages of basal-tafoni weathering and of exfoliation from above on (Riedl, H., 1989, plate 6). In a morphographic way, these remnants resemble the rocking stones of the humid middle latitudes, but must be attributed to an entirely different genesis.

6.1.2. **Pseudokarst features**: On tors with side-tafoni we may observe the development of natural bridges and cave passages comparable to those in carbonate rocks. In both cases, the various exogenous agents affect the evacuation from outside; the corrosion active on carbonate rock, however, is substituted on plutonites by hydration. Most characteristic phenoma may be distinguished on tors: side-tafoni and basal ones induce a cliff-like retreat of the tor sides while ledges, a few metres wide, remain (Riedl, H., 1986, p. 71). The development of these rock platforms is supported by scaling and by hydrolytic processes, which produce pseudo-rillenkarren and weather pits (oricangas) or arrays of weather pits. Forms convergent to kamenicas and solution pits are thus obtained. By retreating into the tor, tafoni weathering at the level of the rock ledges constitutes the most effective process of cliff formation in association with tors. In sum, forms may be distinguished that are morphographically convergent to cryoplanation terraces (Demek, J., 1969), characteristic of periglacial regions of higher latitudes. Both types resemble geologically young facets that are superimposed on the Neogene landforms of the basal surface. In the eu-Mediterranean low-lying areas on the Aegean islands with plutonite bedrock, the dominant agents are hydration, hydrolysis, scaling, and tafoni weathering whereas nivation and frost action induce the periglacial altiplanation terraces.

6.1.3. **Exfoliation** by itself may exercise a substantial influence on the development of the basal surface as illustrated in the area of granodiorites on Naxos (Riedl, H., 1982, p. 20; Weingartner, H., 1982, p. 90). It is evident that the convex sheeting on the "shield" inselbergs that occurs along pressure release joints started only after the Quaternary stripping of the covering blankets. On Seriphos, too, exfoliation must be considered a geologically young process. It set in only after the erosion of the weathered material which released the pressure off the corestones of the basal surface. In the V-shaped, flat-floored valleys and in the V-shaped valleys, originating from pre-Younger Pleistocene times, slopes that exhibit declivities of 35 - 40° and reveal a southern exposure are subject

to convex and continuous desquamation parallel to the slope surface. Involving a consequent smoothing of slopes, the flakes are peeled off with thicknesses of 5 - 20 cm, yet the sheets frequently attain thicknesses >1 m, in some cases 5 - 10 m. Due to the development of basal-tafoni along the margins of the exfoliation sheets such slopes receive a pronounced unevenness. On inselberg crests and on the upper parts of slope, yet not on mid-slopes and footslopes, exfoliation represents a dominant agent of wearing down the inselbergs in a manner that always runs parallal to the surface and conveys convex forms. The products of exfoliation, the gravity detritus, then supply the geologically young coarse block fields developed on the Younger Pleistocene apron-shaped inselberg footslopes. However, as the entire appearance of the convex inselberg crests remains intact, a convergent further development of the upslope elements may be assumed.

6.2. Deep Weathering and Sheet Erosion

Under present conditions, deep weathering (including kaolinization, haematitization, and loamification), which is linked to the primary genesis of the basal surface, is no longer effective. In places where residual matadero blankets have been exempted from erosion, such as in intramontane basins (Bremer, H., 1975) or in relict flat-floored torso valleys, bodies of ground-water have developed. If they are associated with the intramontane basins of highly elevated basal surfaces, they may even be utilized for water supply, as illustrated on Seriphos (Riedl, H., 1986, p. 70).

In these cases as well as on Mykonos (Riedl, H., 1980, p. 33), digging profiles established the existence of ground-water gleys. In a depth of 1 - 2 m, intense reduction processes may be registered. Below 2 m hydration represents the dominant agent that affects the subcutaneous plutonic bedrock even under present conditions. In all areas where matadero marks the remnants of the former surface of relief, networks of rainrills may be detected. On Ikaria (Riedl, H., 1989, p. 204), for instance, they attain depths of 1 - 2 m. These forms of sheetwash are likely to develop in the midst of phrygana where the vegetation cover is sparse due to denudation by grazing. They also constitute typical elements of the Quaternary sedimentary aprons of the inselbergs and of the "kehltäler" on Seriphos (Riedl, H., 1982, pp. 73, 66). These forms, however, result from initial linear erosion on slopes with inclinations of 8 - 11°. Conversely to its dominant impact on the weathered materials at the time of the primary genesis of the former surface, under present climatic conditions sheetflooding is observed only in a few isolated spots (Riedl, H., 1982, p. 34), and it is reduced to the washing away of small quantities of grus and sand in very open parts of the phrygana.

7. The Aegean Basal Surfaces in Comparison to Those of Humid Middle Latitudes

Developed in intrusives and metamorphites, the extensive landscapes of peneplain systems of the humid middle latitudes (e.g. Bohemian Forest) share the Neogene climato-morphologic heritage with those of the Aegean area. The processes of exhumation, however, took entirely different courses:

1) In humid middle latitudes, solifluction during the Pleistocene (flow earth mantles, packs of blocks and loam) may be regarded as the main agent of denudation being responsible for the removal of the weathered materials, whereas the Aegean islands were dominated by sheetwash which started from the pediments of Plio/Pleistocene and Older Pleistocene age and from the Younger Pleistocene glacis.

2) The formation of V-shaped valleys in the course of the prevalent linear fluvial erosion initiated the destruction of the basal surface in the humid middle latitudes. On the Mediterranean Aegean isles this process was brought about by rills formed by initial linear fluvial erosion.

3) In both cases the inselbergs were remolded during the Younger Pleistocene. In the humid middle latitudes this was obtained by forms of denudation, such as frost cliffs and cryplanation terraces. Within the Aegean eu-Mediterranean low-lying areas, undercutting resulted in a steepening of the residual talus slopes. Furthermore, the basal sharply-concave slopes of tropical primary genesis were substituted by forms of accumulation. These elements are distributed as gently-concave aprons that retreat upslope and consist of colluvium, fine-grained sediments, small-sized detritus and allochthonous woolsack-type boulders.

4) Nowadays the tors occurring in the humid middle latitudes are mostly inactive with regard to morphodynamics, whereas on the Aegean islands full morphodynamic activity may be observed. On the one hand the tors are destroyed by tafoni weathering, on the other hand and at the same time, further development is promoted by exfoliation.

5) In both regions the formation of the primary genetic, deeply weathered materials has stopped and sheetwash activities have been replaced by linear fluvial erosion. Brown and red soils, representing the paleosols of humid middle latitudes, are succeeded by recently developed soils resulting in acid Central European brown forest soils, brown podzolic soils, semipodzols, and podzols. On the Aegean islands very similar paleoplastosols form a sharp contrast to the meridional brown soils of recent age.

References

ALTHERR, R. et al. (1982): A late Oligocene/early Miocene high temperature belt in the Attic-Cycladic Crystalline Complex.- *Geol. Jb. E 23*, Hannover, 97-164.

BAKKER, J. P. & H. J. Müller (1957): Zweiphasige Flußablagerungen und Zweiphasenverwitterung in den Tropen unter besonderer Berücksichtigung von Surinam.- *Stuttgarter Geogr. Studien, Bd. 69* (= Lautensach Festschrift).

BREMER, H. (1975): Intramontane Ebenen. Prozesse der Flächenbildung.- *Z. Geomorph., Suppl.-Bd. 25*, 26-48.

BÜDEL, J. (1957): Die "Doppelten Einebnungsflächen" in den feuchten Tropen.- *Z. Geomorph. N.F., 1*, 201-228.

BÜDEL, J. (1957/58): Die Flächenbildung in den feuchten Tropen und die Rolle fossiler solcher Flächen in anderen Klimazonen.- *Dt. Geogr. Tag Wurzburg 1957. Tagungsberichte und Wiss. Abhandlungen*, Wiesbaden, 1958, 89-121.

BÜDEL, J. (1965): Die Relieftypen der Flächenspül-Zone Sud-Indiens am Ostabfall Dekkans gegen Madras.- *Coll. Geogr. Bonn*, 8, 1-100.

DEMEK, J. (1969): Cryoplanation Terraces, their Geographical Distribution, Genesis and Development.- *Rocník 79*, 4, 3-80.

DÜRR, St. et al. (1978): The Median Aegaean Cristalline Belt: Stratigraphy, Structure, Metamorphism, Magnetism.- Closs et al. (ed.): Alps, Apennines, Hellenids. I:G:C:G:Sc. Rep. 38. Stuttgart, 455-477.

DÜRR, St. & V. JACOBSHAGEN (1986a): Das attisch-kykladische Kristallin.- Jacobshagen, V., Geologie von Griechenland, Berlin, 116 - 149.

DÜRR, St. & V. JACOBSHAGEN (1986b): Ostägäische Inseln.- Jacobshagen, V., Geologie von Griechenland, Berlin, 169 - 187.

HEMPEL, L. (1982): Jungquartäre Formungsprozesse in Südgriechenland und auf Kreta.- *Forschungsbericht des Landes Nordrhein-Westfalen, Nr. 3114. Forschungsgruppe Phys. Chemie. Geogr.* Opladen, 1-80.

KELLETAT, D. & D. Gassert (1975): Quartärmorphologische Untersuchungen im Küstenraum der Mani-Halbinsel.- *Z. Geomorph., Suppl.-Bd. 22*, 8-56.
KUBIENA, W. (1955): Les Sols des Territoires Espagnoles du Golfe du Guinée.- *3e Reunion de la C.R.A.C.C.U.S.*, Fernando Po.
KUBIENA, W. L. (1956): Materialien zur Geschichte der Bodenbildung auf den Westkanaren.- *6e Congrès de la Science du Sol, Rapp. Comm., V, 38*, 241-246.
LOUIS, H. & K. Fischer (1979): Allemeine Geomorphologie. Berlin, New York, 4. Aufl.
LOUIS, H. (1964): Über Rumpfflächen und Talbildung in den wechselfeuchten Tropen, besonders nach Studien in Tanzania.- *Z. Geomorph., N.F. 8, Sonderheft*, 43-70.
LOUIS, H. (1967): Reliefumkehr durch Rumpfflächenbildung in Tanganyika.- *Geografiska Annaler, Ser. A., 49*, 256-267.
LOUIS, H. (1975): Abtragungshohlformen mit konvergierend-linearem Abflußsystem. Zur Theorie des fluvialen Abtragungsreliefs.- *Münchener Geographische Arbeiten, 17*.
LOUIS, H. (1976): Prozeßbedingte Singulärstellen, besonders in fluvialen Abtragungssystemen verschiedener Klimate und die Frage nach Reliefgenerationen.- *Z. Geomorph., N.F. 20, 257-274*.
PSILOVIKOS, A. (1986): Contribution to the geomorphology of the southwestern part of the Rhodope Massif (Greek East Macedonia).- *Geologica Balcanica, 16.5.*, 21-32.
RESCH, Th., D. STANGL & H. WEINGARTNER (1989): Tafoniverwitterung auf Thassos. Ein Fallbeispiel.- *Salzburger Geographische Arbeiten, 18*, 77-78.
RIEDL, H. (1980): Leitlinien der geomorphologischen Entwicklung auf Mykonos.- *Exkursionsberichte des Instituts für Geographie der Universität Salzburg, 6*, 116-121.
RIEDL, H. (1981): Landschaft und Formenschatz der Insel Syros.- *Salzburger Exkursionsberichte, 7*, 11-63.
RIEDL, H. (1982): Vergleichende Untersuchungen zur Geomorphologie der Kykladen unter besonderer Berücksichtigung der Insel Naxos.- *Salzburger Exkursionsberichte, 8*, 9-54.
RIEDL, H. (1984a): Geomorphologie der Insel Siphnos.- *Salzburger Exkursionsberichte, 9*, 33-84.
RIEDL, H. (1984b): Die Reliefgenerationen Griechenlands.- *Österr. Osthefte, 26*, 2, 156-176.
RIEDL, H. (1984c): Paleoclimatic Aspects of the Geomorphology of the Cyclad Archipelago (Greece).- *Paléobiologie Continentale, Montpellier IV, 2*, 403-413.
RIEDL, H. (1986): Geomorphologie der Insel Seriphos (Kykladen).- *Salzburger Exkursionsberichte, 10*, 51-97.
RIEDL, H. (1989): Beiträge zur Landschaftsstruktur und Morphogenese von Samos und Ikaria (Ostägäische Inseln).- *Salzburger Geographische Arbeiten, 18* (= Beiträge zur Landeskunde von Griechenland III), 143-243.
SOTIRIADIS, L. D., A. PSILOVIKOS & E. VAVLIAKIS (1981): Granite core-stones and tors in the Vrontou mountains (Greek Makedona).- *Arbeiten aus dem Institut für Geographie der Universität Salzburg, 8*, 63-78.
VAVLIAKIS, E. (1981): Morphologische und morphogenetische Untersuchungen der Abtragungstlächen, Karstformen, Glazial- und Periglazialformen des Gebirges von Menikion. Diss. Thessaloniki.
WEINGARTNER, H. (1982): Tafoniverwitterung in Naxos.- *Salzburger Exkursionsberichte, 8*, 90-110.
WILHELMY, H. (1958): Klimamorphologie der Massengesteine, Braunschweig.
WILHELMY, H. (1961): Klimamorphologie der Massengesteine, 2. Aufl., Wiesbaden.