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THE HUMAN IMPACT ON SOIL EROSION IN GREECE

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ABSTRACT

By example of Tinos Island (Cyclades), investigations were carried out about the processes and features of soil erosion as well as their variation due to lithologic differences. So far, morphodynamic processes caused by man have found little consideration in Greece, although the disastrous consequences of bush and forest fires, of the decay of field terraces and of grazing tracks are generally known. The presented paper aims at encouraging a systematic treatment of quasi-natural processes (MORTENSEN, H., 1955), which show a high degree of applied geographical relevance.

1. INTRODUCTION

The presented investigation focuses on a new aspect of research in Greece calling for an intensified consideration of the border fields between cultural and physical geography (VAVLIAKIS, E., 1993, PSILOVIKOS, A., 1993). The paper tries to point out the consequences of extensification phenomena in the primary economic sector on morphodynamic processes and hence on the course and the intensity of erosion, accumulation and denudation. Due to the anthropogenic influence on these forces, which follow natural laws, we may speak of "quasi-natural" processes. Thus, the recognition of quasi-natural processes represents the guidelines to the proper understanding of present environmental problems in Greece and offers the grounds for landscape ecological reorganisation measures. Tinos, belonging to the Northern Cyclades, was chosen for this case study, because this island represents a typical example for the Greek peripheral living space characterised by a long-lasting population decrease and by the extensification of land use. Moreover, we may distinguish various natural entities that result from the dominance of metamorphitic and plutonic rocks as well as from the distinct relief of ancient and climatomorphologically explainable planation surfaces. This diversity allows the differential analysis of similar causal cycles deriving from the development of quasi-natural processes and association of forms.

Due to this specific constellation, the quasi-natural features of the causal cycle resulting from bushfires could be investigated in the area of the plutonic basal surface relief of Tinos as well as in the region of the schist peneplains and be compared with each other. Extensive goat tracks form another causal cycle. Their morphodynamic effects in relation to location were investigated under three aspects: Sheep tracks on phrygana developed on plutonic "Rampenhänge" in comparison with those on schist peneplains, and furthermore, grazing tracks on field terraces long fallen fallow and nowadays are stocked with secondary phrygana. A third causal cycle is responsible for

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the quasi-natural erosion on slopes bearing dry farming terraces that have fallen fallow for some time and that are not subject to grazing. Finally, a fourth causal cycle concerns the erosional effects along the route of more or less overgrown paths in the schist and plutonic relief.

Last not least, the comparison of the Mediterranean quasi-natural associations of forms with those of the humid middle latitudes touches special aspects of this problem.

2. SOIL EROSION AFTER BUSHFIRES ON TINOS

2.1. Location on plutonic planation surfaces

The scene of the fire covers 600 m^2 and is situated 1,5 km NNE of Phalatados at an altitude of 480 - 490 m. The E-facing area lies on an inselberg slope in the midst of the granite planation surface (average altitude: 430 - 450 m) of the Anomeri Range. The slope shows an inclination of 18° and is covered with "wool sack"-shaped boulders. In 1991 shepherds burnt down the stands of *Erica arborea* and *Poterium spinosum* in favour of the annuals in order to gain a higher calorie basis for the fodder of their goats.

2.1.1. Beginning of rain rill formation

In the spring of 1991 rain rills began to develop in the chemically deeply weathered granite rock (matadero weathering). After a narrow, horseshoe-shaped start, the rills attained a length of 2 - 4 m and an incision of 10 - 15 cm. The microridges between the rills had been generally lowered by erosion by 5 - 10 cm in comparison with pre-fire times. In February 1992, following the heavy winter rains, the slight initial rills of 1991 had been modified into a V-shaped profile with a further incision of 10 - 15 cm, exposing the rootstocks of *Poterium*. The density of the lateral gullies increased, the ridges in between were subject to increased sheet erosion, the amount of denudation then totalling 10 to 17 cm. In the gully cuts, the total amount of denudation ran up to 20 - 30 cm in comparison with pre-fire times.

2.1.2. Formation of ravine-like microforms of soil erosion

In those parts of the fire scene that are intensely grazed by goats we observe soil cliffs, about 15 - 20 cm high and with courses shaped like small embayments. Their formation is obviously promoted by the goat tracks. In this case, sheet-wash replaces the shallower goat tracks by steeper cliff fronts, which preferably form in the lee side of burnt rootstocks of phrygana. The progressive retreat of the cliff includes the development of ravine-like microforms that lead to the irreparable exposure of the rootstocks (SAVINA, M., 1993). It is a significant fact that in the course of the dynamic process of their formation we note the advancing exhumation of in-situ "wool sack"-shaped boulders. Boulders, as large as 4.5 m^3, lie on a foundation of decomposed matadero, only about 20 cm thick. The matadero cover, unprotected from erosion by the boulders, has been removed by 20 cm, as matadero coatings prove that we discovered at this height on a boulder.

2.1.3. The general impact of the consequences of the fire

The example of the strongly weathered plutonic peneplan relief signifies that it took erosion only a few months to remove the rankar as well as the transition horizons A/C_{m1}. During the second winter-humid season following the fire, even parts of the C_{m2} horizon (KUBIENA, W., 1955) had been eroded. The agents responsible for this process are initial linear fluvial erosion and selective sheet flood (for example, ravine-shaped microforms depending on residual rhizospheres). The correlate sediments of the silty-sandy top soil are found on the flatter basal slopes that show a gradient of 5°. They reveal

a circular pattern of accumulation. The main trend of the quasi-natural erosion in the sensitive matadero horizons aims at the intensified exhumation of the subcutaneous "wool sack"-shaped boulders. In consequence, their density is relatively growing, and at the same time the value of such sites for grazing is reduced.

2.2. Location on schist slopes

Similar to the location on plutonic rock, the consequences of the bushfire have lead to a complete change of the morphodynamics in the schist relief, too: morphodynamic stability has been replaced by instability. The site is located in the area of the Lower Schist series (MELIDONIS, N., 1980, p. 5) in the valley of Katomeri, about 2 km north of the road saddle of Zoodochos Piji. It lies in an altitude of 160 - 190 m on an east-exposed slope that reaches from the edge of a pediment down to the valley of Kallani. The fire took place in 1985 when due to flying sparks, the phrygana caught fire on an uncontrolled dump nearby. Since then, between 5 and 23 % of the 20 - 25°-inclined slopes have been covered by lignified shrubs.

2.2.1. The mobilisation of Würmian alluvial debris covers (Fig. 1)

It seems quite essential that in this case the slope is developed on deeply weathered phyllitic mica schists. They are covered down to a depth of 1 - 2 m by Würmian alluvial debris, that often reaches pocket-like into the basal phyllites. This type of sediment, originating from a glacial period, consists of detritital, strongly quartzose phyllite mica schists with longitudinal axes of 5 - 35 cm. The material is embedded in a brown-reddish to yellow-brownish matrix of grus and sand. The whole complex is modified by recent meridional brown soil.

The slope is characterised by numerous, 1 m long rills that exhibit a clear span of about 20 cm and a depth of 15 cm. They occur on the brown soil as well as on the relict alluvial debris, which leads to a recent rebedding of the material in the rills. The debris is undercut not only by rills, but also by microcliffs that attain a height of 0.50 - 0.75 m. Quite frequently, the foot of the cliff already rests on the mica schist layer, so that outcrops of bedrock appear which in turn serve as the recent supplier of debris. These cases illustrate that the mostly relict alluvial debris is already denuded. The mobilisation of the fossil debris and the active debris production on the exhumed outcrops of bedrock largely contributes to the present debris accumulation on the slopes.

2.2.2. The general impact of the consequences of the fire

In the case of fire, slopes that reveal cataclinal structures on metamorphites and, moreover, are covered with relict alluvial debris represent a highly unstable system: The infiltration capacity of precipitation is highly reduced, which promotes the formation of rills and ravine-like microforms of erosion. Consequently, the relict, already consolidated slope debris is exhumed and, with the loss of the matrix, starts moving. When the quasi-natural erosion reaches the rock floor of the slope, the rill erosion changes to sheet erosion, which, of course, is also determined by lithology and structure. Within 6 years, we have noted a large-scale skeletonisation of the slope displaying physiognomic features similar to those of arid regions. The hamada-like development of the slope, the mobilisation and the fresh production of debris largely prevent the rise of a secondary phrygana. So, 6 years after the fire, the dominance of quasi-natural denudation over the recolonisation through vegetation and over soil formation has led to a picture that reminds us of a semi-desert.

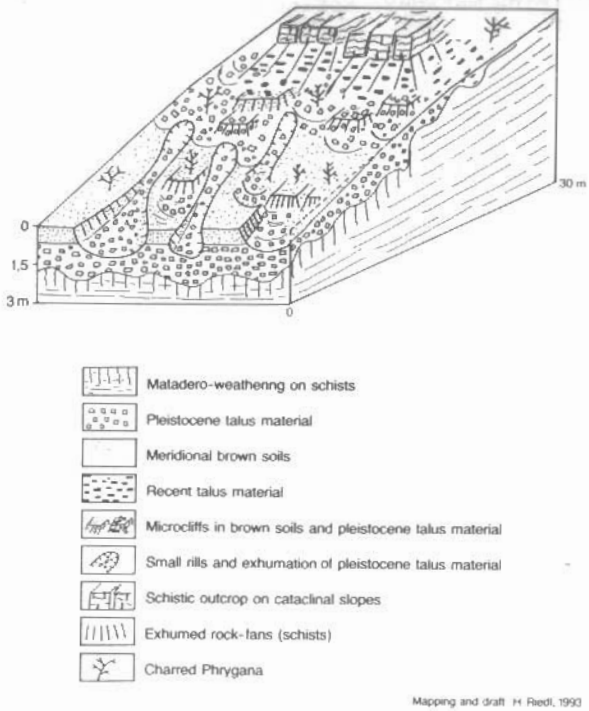

Fig. 1: Erosive - denudational features resulting from bush fires on slopes of schistic rocks.

3. SOIL EROSION ON TINOS CAUSED BY PASTURING

Both geologic units of the island, plutonic as well as schistic, have been used for grazing since old times, leaving no traces of any predominant farming. Both case studies, though lithologically different, display a common feature: They are located on the "Rampenhänge" (LOUIS, H. and FISCHER, K., 1979) of the respective basal surface (RIEDL, H., 1991) belonging to Latest Tertiary peneplain sequences and they are characterised by relatively deep residuals of the syngenetic, chemically weathered detritus (matadero horizons). In both cases we may distinguish examples of quasi-natural elements of form.

3.1. Location on the plutonic planation surface

The investigated area is situated in the wide saddle area of the Anomeri at an altitude of 460 - 470 m, 2 km north of Falatados. The prevailing rock is granite (fig. 2).

3.1.1. Zone of patches of sheet erosion

Garrigue, showing a maximal height of 1.5 m and consisting of *Poterium*, *Erica arborea* and Callicotome, stocks on the 2°-inclined "Rampenhänge" that are covered with boulder-poor decomposed matadero. Goat tracks, 20 cm wide, form knot-like bundles. At junctions of these tracks, we observe shrubless areas of 5 - 10 m^2 that are marked by erosive processes. These patches of sheet erosion undercut the marginal phrygana and garrigue so that micro-cliffs, 3 - 4 cm high, develop laterally in the 0 and A-horizons of the recent rankar. They are covered with annuals that grow on silty fine sands. A light-grey, rippled dehydration crust coats the patches. 0.5 m long tongues of grus

approach the silt crust laterally and indicate a small-sized grain sorting in the course of sheet erosional processes.

3.1.2. The transitional zone from sheet erosion to rill erosion

Subsequent to the forms introduced in 3.1.1., we observe a second element of the sequence (RIEDL, H., 1989). On "Rampenhänge" with inclinations of 3°, niches develop along the goat and run off tracks that are 1 m long and that are entrenched into the topsoil up to 0.4 m deep. Due to this process, the rhizosphere of *Poterium spinosum* is laterally undermined which leads to a loss of vitality in the above-ground parts of the shrubs.

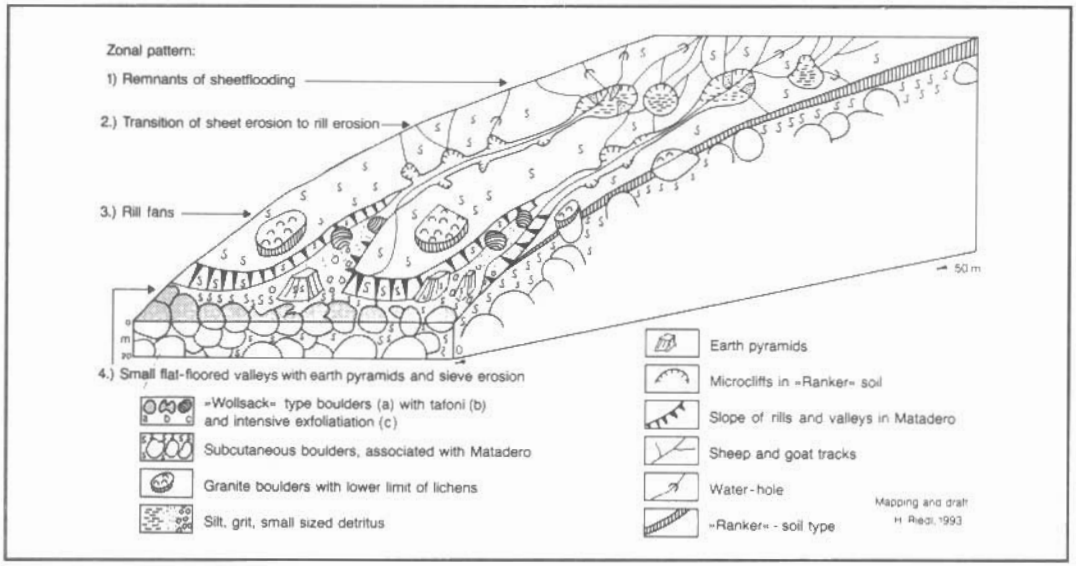

Fig. 2: Erosive - deudational features associated with sheep tracks on plutonic basal surface relief

3.1.3. Zone of gully fans

On "Rampenhänge" with inclinations of 4° we find a third element of sequence formed by gullies with a clear span of 2.5 - 6 m and an incision of 1 - 2 m to the utmost. Their side slopes show gradients of 10°. The "wool sack"-shaped boulders found in the gully cuts are characterised by recent intense granular disintegration and fine scaling. Within the gullies, the capillary fringe of the soil moisture is raised so that tafoni-like notches develop on the granite boulders. initial fluvial linear erosion forms entrenchments into the decomposed matadero as well as into the simultaneously disintegrating "wool sack"-shaped boulders. This incision based on quasi-natural erosion amounts to 40 cm; in contrast, sheet erosion affecting the ridges of the "Rampenhänge" between the gullies only runs up to 3 cm, which is indicated by lichen boundaries. If the inclination of the "Rampenhänge" increases up to 5°, channels with a length of 30 m exhibit lateral erosive bottoms filled with washed out sands, grus and fine detritus. Earth pillars, 1.5 - 2 m high, rise badland-like from the funnels of 4 m wide channel bottoms.

3.1.4. The zone of distal small flat-floored valleys

In some cases the pastures border on block steps that show a height of several decametres and that drop down to intramontane basins. The "Rampenhänge" above the scarps crop out into the air. This situation is associated with the

fourth sequential element of quasi-natural soil erosion which comprises the features of sieve erosion: The zone of gully fans ends abruptly at the scarp, developing marginal breaks, 3 m high, in the decomposed matadero. The distal scarp is characterised by an abundance in boulders and exercises a sieve drainage effect. The gully runoff is drained by numerous fissures and weathered passages (THEODOROPOULOS, D., 1975) without dissecting the scarp. The change from flat-floored valleys to cliff funnels is located exactly at the transition from initial fluvial linear erosion, typical of the dominant decomposed matadero, to sieve erosion that is prevailing in the steep relief of residual boulders.

3.1.5. The general impact of pasturing on the gentle plutonic relief

All in all, we see that the gently inclined features of climatomorphologic heritage (RIEDL, H., 1984), situated on the higher elevated planation surfaces, are not to be associated with a present-day general absence of denudation. On the contrary, the whole sequence proves that pasturing (goat track junctions, resting places, tanks filled with rain water, etc.) releases erosional processes even on a most gently inclined relief. We may recognise that the ultimate effect of these processes is the extensive exhumation of the ancient basal surface including the destruction of boulders by hydration. Yet, erosional processes triggered off by anthropogenic activities contribute considerably to the recent modification of the old forms.

3.2. Location on the schist relief

The site is situated at an altitude of 620 - 640 m in the mica schistose area of Mt. Mesovouni (Polemokampos Range). The elevated plains are used as pastures and are stocked with a dense phrygana composed of ericaceae. In contrast to the plutonic areas on Tinos Island, the pre-existing peneplains are characterised by a modified morphology. The steep slopes of the detritus-covered and tor-topped inselbergs as well as the surrounding elevations end in form of slope concavities on the "Rampenhänge". Comparable with the plutonites, we distinguish subcutaneous boulder formation in a similarly structured decomposed matadero; their density, however, is less. Furthermore, platy structures prevail over rounded ones. As compared with the granite relief, sieve erosion, therefore, plays a minor part in the distal and proximal parts of the "Rampenhänge". Basically speaking, we observe the same sequence of quasi-natural features as on plutonic rock, the sequential elements, however, shift to areas with slightly steeper gradients. In comparison with the plutonic part of the island, not only the patches of sheet erosion occupy steeper slopes (a maximum of additional 3°), but also the zone of rill fans shows a maximum change of +4° in the proximal parts and of +2° in the distal ones. The causes for these differences lie in the dissimilar type of weathering. In comparison with plutonic rock, a larger amount of grus and a considerable quantity of small debris is produced on schist. Consequently, a slightly higher potential energy is reached to overcome larger frictional resistance in the course of erosive processes. Due to the absence of any restrictive effects of sieve erosion on the quasi-natural rill erosion and due to the higher potential energy of these pastures on the schist peneplains, rill fans start to form badland-like gully niches subsequent to a transitional zone. These niches develop small walls in the decomposed matadero that are 0.5 - 0.7 m high. Those covering an area of 15 m^2 often reveal half a dozen of pseudo-"tilke"-shaped run-offs following goat tracks. In the course of rill fan formation, we soon note the distal development of earth pillars, earth pyramids (BECKER, H., 1966) capped with boulders from in-situ weathered schist and similar forms without boulders.

3.3. The general significance of pasturing on the schist planations surfaces

Due to the specific weathering of schist and due to the erosive effects of the higher potential energy, we distinguish more excessive stages of young quasi-natural erosion released by goat tracks than in the plutonite relief. The peneplains on mica schists react more sensitive on human impact.

4. SOIL EROSION ON UNCULTIVATED FARMLAND

4.1. Long-deserted field terraces

The site chosen for the case study is located at an altitude of 460 - 480 m on the SW-exposed slope of Mt. Xovouni, belonging to the area of the granite planation surface. Since 1940, 7 well-distinguishable terrace levels with today mostly ruined dry walls have fallen fallow and have been turned into extensive pastures. Inclinations change from 10° in the lower parts to 20° in the upper ones. The abandoned farmland is totally occupied by *Poterium spinosum, Pistacia lentiscus, Erica arborea* and, sporadically, by *Quercus aegilops* with trunk diameters of 15 - 20 cm.

4.1.1. Marginal erosion and double cliff formation

If the walls of the formerly cultivated terraces are partially ruined, microrill erosion predominates on the decomposed matadero. In that case, closely adjoining miniature embayments cause the former terrace surface to retreat from the former distal wall edge by developing 20 cm high cliff fronts. The former stone walls are traced by a basal, 0.5 m-high main cliff developed in the matadero horizons. The secondary lower cliff proves a loss of soil across a width of 1 - 1.5 m, a length of 10 m and a depth of 20 cm in the course of 50 years. Calculated for a terrace length of 10 m, the average loss of soil amounts to 2.5 m^3 and an annual quasi-natural rate of erosion of 0.05 m^3. Hence we may conclude that, related to a terrace surface of 1 m^2, 5/1000 m^3 (or 5000 cm^3) of soil have been eroded per year.

4.1.2. Triangular-shaped slopes - rainrills - gully associations

In this case and contrary to 4.1.1., the terrace walls have fallen completely desolate. Behind the former anthropogenic terrace heads, we now observe the mouths of rills that are entrenched into the former field terraces up to 1 m deep. They cut through the A/C_{m1} and C_{m2} horizons and, due to the collapse of the stone walls, they are adjusted to the local erosion base level of the next man-made terrace below. They are characterised by steep gradients and a maximum clear span of 1.7 m; they are succeeded by small alluvial cones. In between these features, triangular-shaped slopes have developed that display bifurcating rain rill systems. The slopes on decomposed matadero cut into the subcutaneous "wool sack"-shaped boulders, which, under the influence of the rill system, are subject to an increased recent production of grus. The bases of the small triangular-shaped slopes retreat as a whole forming concavities that are adjusted to the lower cultivated terrace. The process, though taking place on a smaller scale, may be compared with that of the pediments. Due to the activities of quasi-natural morphodynamics, the slopes and gully sides are devoid of woody plants of the phrygana. Due to the impact of all these dynamic processes, the terraces may be completely eroded so that the vertical intervals as well as the potential energy may increase twice the original amount. This development strongly accelerates the attacks of initial erosion on the respectively higher former terrace surface.

4.1.3. Association of dells, goat track gullies and microterraces

This group of forms proves the partial responsibility of goat tracks for the erosion of field terraces. Dells with spans of 2 m and depths of 0.75 m

reach across several decayed field terraces, whose wall crests are destroyed with special intensity. In combination with the dells, we always find gullies resulting from goat tracks that cut into the dells as well as into the terrace surfaces up to 30 cm deep. The gullies display a keyhole-shaped cross profile and are frequently characterised by a second order, tree-like pattern that runs in a rectangular angle to the main gully. Goat tracks on the steeper upper parts of the slopes lead to numerous microterraces that are often only a few cm high and are dislocated against each other. Annuals dominate the vegetation cover.

4.1.4. Effects of soil sheeting and goat tracks on the upslope terrace surfaces

If the former field terraces occupy decomposed matadero that reaches down only pocket-like between the "wool sack"-shaped boulders, the height of the terraces may fall below 50 cm, and we note an adjustment of the unclutivated terraces to the general inclination of the slope. In this context, the resting places of the goat herds play quite a significant role. The animals rub themselves on the 15 - 20 cm thick recent rankar and practically sheet the soil off the metamorphic rock. The detrital rankar is quickly removed from gently convex granite hummocks by sheet erosion or blown off by mountain winds during the dry season. A further skeletonization of the recent A/C soils is achieved through the formation of goat track terraces that develop in the course of browsing on annual-covered areas.

4.1.5. The general significance of pasturing on long-derserted field terraces

In contrast to the areas of persistent grazing, no sequences may be distinguished in the category of case studies introduced above. This fact may be explained by the individual degree of decay of the various terrace walls and, furthermore, by the original heights and widths of the field terraces which promote the impact of local erosion levels bases. Nevertheless, several superordinate regularities may be pointed out:

a) The association of forms described under 4.1.2. is closely related to slopes with a gradient of 10°. The goal of quasi-natural erosion may be considered in the retreat of the slope and in the extension of the relict and natural basal concavities at the margins of the intramontane basins towards the slopes of the inselbergs. In this case, quasi-natural morphodynamics continues the course of the relict processes.

b) With the generally increased density of boulders in the upper parts of the slopes, the basal zone of initial erosion is receding. Due to grazing activities, quasi-natural denudational and aeolian forces (cf. 4.1.3.) prevail in combination with sheet erosion on the formerly cultivated fields upslope.

4.2. Recently deserted field terraces

Adjacent to the location analysed under 4.1. and occupying a similar altitude, a cluster of former field terraces continues towards E on the slope of Mt. Xovouni. The footslope is characterised by an inclination of 2°, the gradient of the lower parts amounts to 9°, that of the sections above shows 25°. The terraces fell fallow 25 years ago, the stonewalls, however, have mostly stayed intact. 80 - 90% of the terrace surfaces are covered with phrygana with prevailing Poterium, *Pistacia lentiscus* and deciduous oak trees are missing. The pre-existing inclinations of the slopes and the state of preservation of the walls play an essential role for the degree of quasi-natural denudation.

4.2.1. Zone of accumulation at the foot of the terrace steps and of sheet erosion

The described area is 20 m wide and borders on the 2°-inclined foot of the terraced slope. Those parts proximal to the terraces exhibit accumulations of grus, the distal ones are characterised by accumulations of silt and fine sands. In the accumulation area the cover with Poterium is reduced to 10 - 30%, stripes of annual vegetation, however, are always inserted. Stripes or circles of silt always surround the thickets of mature phrygana.

4.2.2. Zone of gently inclined slopes bearing damaged walls and the erosion of the terrace edges

In the illustrated example, the slope gradient shows only 9°, the walls are only 0.5 m high. That is why even smaller damages on the walls are already significant for the initial erosion. The terrace surface was generally deepened up to 20 cm below the wall crests in those parts proximal to the edge. Groups of 5 - 10 cm high earth pillars, found in the terrace surface distal to the edges, designate the original height of the soil. In the rain rills between the earth pillars, alluvial microfans out of grus are formed.

4.2.3. Strongly inclined slopes with intact stone walls and mostly preserved terraces

A devegetated erosional strip, only a few dm wide, borders on the edge of the stone walls that attain a maximum height of 1 m. In relation to the outward gradient of the intact terrace surface it exhibits a reverse incline towards the inside. The strip lies 5 cm below the wall crest and forms a 20 cm high soil cliff in the preserved, phrygana-covered terrace surface. Marginal sheet wash induces the skeletonization of soil by washing out the fine grained fractions and by removing them. Another significant effect is achieved by the subcutaneous undercutting of the terrace close to the wall, as microcones of grus and sand at the foot of the wall indicate. Their tops protrude out of the bare-washed, unstabilized joints of the stonework. They resemble the correlate sediments of the erosional strips. Besides, other agents work on the erosion of the edges of the uncultivated terraces: They are dynamically enforced turbulences of stationary eddies that blow out fine materials. The shrub-covered uppermost terraces on such slopes do not reveal this marginal erosional phenomenon, instead, they are in a process of initial destruction. In accordance with the original inclination of the field terrace of 3°, microhorst-like accumulations of soil are formed by rill wash. The relative heights of these forms rise from 3 cm at the wall top to 25 cm at the foot of the next wall upslope.

4.2.4. The general significance of the initial destruction of field terraces

The primary inclination of the slope and the structural state of the stone walls are essential factors for the initial decay of field terraces. Low walls built on gently dipping slopes tend to collapse relatively quickly, and the local rill erosion level of the residual walls controls the depth of terrace erosion. In the case of steeper slopes and higher walls, the persistence of the wall tops seems to be greater. Yet, due to the larger potential energy, subcutaneous washout becomes a decisive element that may be traced down to the margins of the terraces. This results in the lowering of the local erosion base level for the surface rill wash, which may even affect areas beyond still intact wall crests and which, in turn, brings about their growing instability.

5. PATH EROSION

5.1. Path erosion on schist

In the area of the Polemokampos Range we find an instructive example of erosion on decayed, untended bridle paths. The broad old trail probably goes back to Venetian times and is still partially paved and lined by walls. It leads from the saddle near the monastery of Zoodochos Piji across the Karampina Ridge to the saddle west of Mt. Kastron, following a hilly area with field terraces fallen fallow 80 to 90 years ago. Since then, 3 m deep, canyon-shaped gully systems have cut into the bridle trail. In due course, the same gullies dissect Würmian alluvial debris down to the bedrock. It seems an essential fact that, due to runoff concentration along the desolate path, the annual amount of quasi-natural erosion runs up to 3.3 - 3.7 cm, which is 100 times the amount of natural erosion, measuring 0.3 mm in areas bordering the trail. This example may serve as evidence that untended paths in mica schist areas exercise an intensifying effect on erosion.

5.2. Path erosion in the plutonic relief

Quite impressive examples of path erosion along bridle trails still in use are delivered on the granite planation surfaces of the Anomeri Range. Along the trails which are carved into the gently inclined (3°) "Rampenhänge", we observe the formation of bifurcating gully systems on weathered matadero that are incised into the path level up to on 1 m deep. The outcrops of weathered matadero between the gullies are devoid of vegetation and signify the present degree of sheet erosion. The lateral border of the trails is often accompanied by cliffs with heights of 3 m. Quite frequently, we observe a distinct lateral retreat of the matadero cliffs due to denudational forces. Granular disintegration and sheeting induce the exhumation of the subcutaneous "wool sack"-shaped boulders so that, in consequence, earth pyramids capped with boulders appear along the sides of the bridle trail. These forms reveal a great similarity to the tuff cones of Middle Anatolia (BECKER, H., 1966, p. 66). The initial quasi-natural deep-reaching path erosion lowers the local erosion level for the sheet erosion on the "Rampenhänge". The effect of the bridle paths as recipient reaches a few decametres beyond the paths so that the "Rampenhänge" within this area are erosively dissolved by gully erosion.

6. SOIL EROSION IN THE MEDITERRANEAN REGION IN COMPARISON WITH THAT IN HUMID MIDDLE LATITUDES

In humid middle latitudes the consequences of the economic structural changes from labour intensive livestock husbandry to a labour extensive one have long been investigated in the montane and subalpine levels of the Eastern Alps (RIEDL, H., 1983, 1987), with special consideration of the bio-, pedo, and morphospheres. The comparability with the Mediterranean island of Tinos is given only to a certain extent because of the winter snow cover lasting for several months.

6.1. Dissimilarities

Due to the last-mentioned characteristic, the extensive high-altitude pastures exhibit a number of quasi-natural features resulting from changed forms of pasturing and from the discontinuance of accompanying measures of *environmental preservation. Instructive examples of such forms are quasi-*natural ravines originating from snow scouring, landslides due to nivation, and sheet flow in the course of snow melt, all of them occurring on schist (Scythian Werfen strata, mica schists of the Lower Tauern). In plutonic areas, as for instance in the Bohemian Massif, the montane level of altitude is marked by stable morphodynamic conditions, in spite of pasturing.

The Mediterranean grazing areas differ from the alpine ones primarily by the domination of quasi-natural initial linear fluvial erosion which is coupled with quasi-natural sheet wash.

6.2. Convergences

Similar quasi-natural features may be distinguished in the following cases, considering the different situation of the genetic factors:

6.2.1. Mobilisation of relict detritus

Detrital slopes are typical for alpine areas near the timberline, when packages of relict, late-glacial migratory detritus are undercut, exhumed and mobilised due to snow scouring processes and landslide dynamics that set in the course of dwarf shrubbery starting to grow on the **extensified** high-altitude pastures.

6.2.2. Sheet erosion

In the Mediterranean regions, patches of sheet erosion may be regarded as the general accompanying quasi-natural dynamics of rill erosion. In the subalpine level of the Alps we observe similar phenomena only as a consequence of soil compaction resulting from overgrazing and of the following sheet flooding by melt water.

6.2.3. Microcliffs

In contrast to the Mediterranean small livestock, the alpine cattle produces so-called "Viehgangeln": These tracks, often winding along for several kilometres, terrace the slopes. They attain a relative height of 1 m and cut the contours under an acute angle. In the course of the changes in pasturing which includes the complete reduction of personnel, the cattle has generated furrows of tracks that run vertical to the contours and that represent a cliff-shaped entrenchment into the fronts of the older microterraces. This process also induces the sheeting of the grass cover. These cliffs reveal a similarity to the microcliffs on the long-deserted Mediterranean field terraces and in burnt-down areas both being grazed by sheep and goats.

6.2.4 Gully Ravines

In contrast to the Mediterranean region, where rill and gully erosion already appear on slopes with very gentle inclinations, these features are predominant in the humid Alps only on slopes with gradients >20°. Due to the maintenance of the gully run-off by its concentration in the decayed paths, leading to and from the alpine pastures, as well as by the complex effects of snow scouring, nearly devegetated gully systems may develop in the areas of pasturing. These features - even the formation of badlands and earth pillars - are quite similar to those of the Mediterranean gully systems which, however, are completely based on heavy rainfalls. Both, however, may be regarded as results of the interaction of quasi-natural forces.

7. CONCLUSIONS

By example of Tinos Island, the differential analysis of the quasi-natural features reveals a high portion of anthropogenic impact on the present-day processes of soil erosion. Former studies on the island of Siphnos (RIEDL, H. and KALSS, R., 1983) make evident that the secondary phrygana, which appears in the course of the decay of cultural terraces, does not represent any effective protection against erosion. This protection is guaranteed only by completely undamaged terrace walls. This has been proved across a span of three thousand years by the ecological experience of Greek farmers and, lately, by the presented investigations about the stages of initial erosion. The slightest extensification of

Mediterranean field terraces brings about the inevitable collapse of the ecological system that has been artificially kept at equilibrium. Furthermore, the areas affected by fires prove to be most endangered by erosion, even more so, as they are used for grazing. Within a very short time we observe the radical erosion of fine materials and a fast areal extension of boulders, sharp-edged detritus and of the uncovering of base rock. Within a very short period, sites that were subject to fires, have fallen fallow, without any chance to be used for farming. Grazing on slopes with the shallowest inclinations triggers off their dissection, even if a dense covering with garrigue is given and no fire has occurred. Regarding the last-mentioned facts, the comparison with the humid middle latitudes shows the significance of considering the quasi-natural course of processes within the larger ecological zones of the earth with the hope to control them systematically in due time. The quasi-natural, very recent features of the Mediterranean region illustrate the enormous sensitivity towards the initial linear fluvial erosion, which actually represents the elementary macrozonal characteristic of the semihumid subtropical zone in contrast to the humid middle latitudes.

REFERENCES

BECKER, H. (1966). Vergleichende Betrachtung der Entstehung von Erdpyramiden in verschiedenen Klimagebieten der Erde. *Kölner Geographische Arbeiten*, Vol. 17, Wiesbaden, pp. 20 - 112.

KUBIENA, W. (1955). Les Sols des Territoires Espangnoles du Golfe du Guinée. 3e Reunion de la G.R.A.C.C.U.S. Fernando Póo.

LOUIS, H., and FISCHER, K. (1979). Allgemeine Geomorphologie. Berlin - New York, 814 pp.

MELIDONIS, N. (1980). The Geological Structure and Mineral Deposits of Tinos Island (Cyclades - Greece). *Institute of Geological and Mineral Exploration* - Athens, 1980, Athen, pp. 1 - 80.

MORTENSEN, H. (1955). Die quasinatürliche Oberflächenformung als Forschungsproblem. *Wiss. Zeitschr. d. E. Moritz Arndt-Univ. Greifswald*, Vol. 4

PSILOVIKOS, A. (1993). The Main Physiogeographical Problems of Northern Greece (Thrace and Macedonia). *In: H. RIEDL (ed.), Beiträge zur Landeskunde von Griechenland IV; Salzburger Geographische Arbeiten*, Vol. 22, Salzburg, pp. 9 - 34.

RIEDL, H. (1983). Die Ergebnisse des MaB-Projektes "Samer Alm". Ein Beitrag zur sozioökonomisch gesteuerten Veränderung subalpiner Landschaftssysteme. *Österreichische Akademie der Wissenschaften; Veröff. d. Österr. MaB-Progr.*, Vol. 5, Innsbruck, pp. 3 - 114.

RIEDL, H. (1984). Die Reliefgenerationen Griechenlands. *Österreichische Osthefte*, 26, Wien, pp. 52 - 72.

RIEDL, H. (1989). Geomorphological sequences in the Attic-Cycladic region. *Geographica Rhodopica*, Vol. 2. Thessaloniki; 2nd Hellenic - Bulgarian Symposion, pp. 87 - 94.

RIEDL, H. (1991). Landforms and Processes Associated with the Exhumation of the Plutonic Basal Surface in the Area of the Aegean Archipelago. *Bulletin of the Geological Society of Greece*, Vol. 25/4, Thessaloniki, pp. 67 - 82.

RIEDL, H. and KALSS, R. (1983). Beiträge zur aktuellen Bodenerosion der

Insel Siphnos. *Salzburger Exkursionsberichte*, Vol. 9, Salzburg, pp. 187 - 202.

RIEDL, H., ed. (1987). Beiträge zur Landschaftsökologie der Salzburger Kalkalpen, mit besonderer Berücksichtigung der sozioökonomischen Prozeßsteuerung. *Veröff. d. Österr. MaB-Progr.*, Vol. 12, Innsbruck, pp. 5 - 354.

SAVINA, M. E. (1993). Some Aspects of the Geomorphology and Quaternary Geology of Grevena Nomos, Western Macedonia, Greece. *In: H. RIEDL (ed.), Beiträge zur Landeskunde von Griechenland IV; Salzburger Geographische Arbeiten*, Vol. 22, Salzburg, pp. 57 - 75.

STIBOREK, R. (1990). Die Bevölkerungsentwicklung der Kykladen unter besonderer Berücksichtigung der Volkszählungen 1961 - 1981. *Dipl.Arb. Nat. Fak. Univ. Salzburg*, 127 pp.

THEODOROPOULOS, D. (1975). Tafoniverwitterung auf der Insel Tinos. *Ann. Géol. Pays hellèn.*, 26, pp. 149 - 158.

VAVLIAKIS, E. and SOTIRIADIS, L. (1993). Die aktiven Qanatsysteme in Griechenland. Untersuchung der aktiven Qanatsysteme der Provinz Phyllis (Nomos Serres) aus morphologischer und hydrographischer Sicht. *Festschrift H. Riedl; Salzburger Geographische Arbeiten*, Vol. 25, Salzburg, pp. 193 - 206.