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GEOMORPHOLOGY AND EVOLUTION OF THE REGION BETWEEN LAPA AND ELEOTOPOS, NORTHWESTERN PELOPONNESUS (GREECE)

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ABSTRACT - *Geomorphology and evolution of the region between Lapa and Eleotopos, northwestern Peloponnesus (Greece)* - Il Quaternario, **7**(2), 1994, 537-544 - The northwestern part of Peloponnesus (Greece) between the villages of Lapa and Eleotopos (37°56', 21°14', 38°05', 21°30') is characterized by a series of morphological units: a) a mountain front, b) an ancient piedmont passing seawards in to a wide terraced area, c) a coastal plain with marshes. Geological and geomorphological analyses of the area suggest the following evolution. Before or during isotopic stage 7, and as a consequence of an extensional tectonic pattern, a sinking of the Ionian zone flysch was followed by a sea transgression and by the creation of a wide bay near the Skolis mountain front. In this bay, a marine-lagoonal succession was deposited during isotopic stage 5. After isotopic stage 5, a regression occurred and marine deposits were covered by alluvial and colluvial sediments which created a wide "pediment" and alluvial fans. The extensional tectonics dislocated these sediments, showing uplift at the mountain front and lowering downward in the valley. The last lowering is represented by alluvial deposits in the coastal plain. These deposits were incised and terraced (New Vouprassio terrace) due to a new local tectonic action. This new plain is Holocene in age. Of special interest is the post-Tyrrhenian fault scarp which dislocates the Varda terrace from the Vouprassio terrace.

RIASSUNTO - *Evoluzione geomorfologica della regione tra i villaggi di Lapa ed Eleotopos nella parte nord-occidentale del Peloponneso (Grecia)* - Il Quaternario, **7**(2), 1994, 537-544 - La parte nord-occidentale del Peloponneso, tra i villaggi di Lapa ed Eleotopos (37°56', 21°14', 38°05', 21°30'), è caratterizzata dalla presenza di una serie di unità morfologiche, così sintetizzabili: a) un *"mountain front"*, b) una antica zona pedemontana, oggi terrazzata, c) la piana costiera attuale, in parte occupata da una palude. L'analisi geologica e geomorfologica dell'area ha consentito di ricostruire la seguente evoluzione. Prima (o durante) l'intervallo di tempo comprendente lo stadio isotopico 7, in conseguenza di un regime tettonico distensivo, si determina un ribassamento verso mare del flysch della zona ionica con conseguente invasione marina con deposizione, al piede della scarpata di faglia del monte Skolis (il *"mountain front"*) di una successione marina che, a luoghi, è lagunare. In seguito ad una regressione marina, successiva allo stadio isotopico 5, tali depositi vengono ricoperti da sedimenti alluvionali e colluviali formanti un ampio *"pediment"* con alcuni conoidi di deiezione. La tettonica disloca poi questi sedimenti, sollevandoli a monte (consentendone pertanto la profonda reincisione (terrazzo di Varda) e ribassandoli a valle dove essi sono stati ricoperti dai depositi alluvionali di una piana costiera, anch'.essa reincisa e terrazzata (terrazzo di Nuovo Vuprassio) forse in seguito ad un nuovo, piccolo evento tettonico. Questa piana è sostanzialmente di età olocenica. Particolarmente vistosa è la scarpata di faglia successiva al Tirreniano che separa il terrazzo di Varda da quello di Vuprassio.

Key-words: Geomorphology, mountain front, terraces, coastal plain, Tyrrhenian, Holocene, Lapa, Eleotopos, Peloponnesus, Greece
Parole chiave: Geomorfologia, fronte montuoso, terrazzi, piana costiera, Tirreniano, Olocene, Lapa, Eleotopos, Peloponneso, Grecia

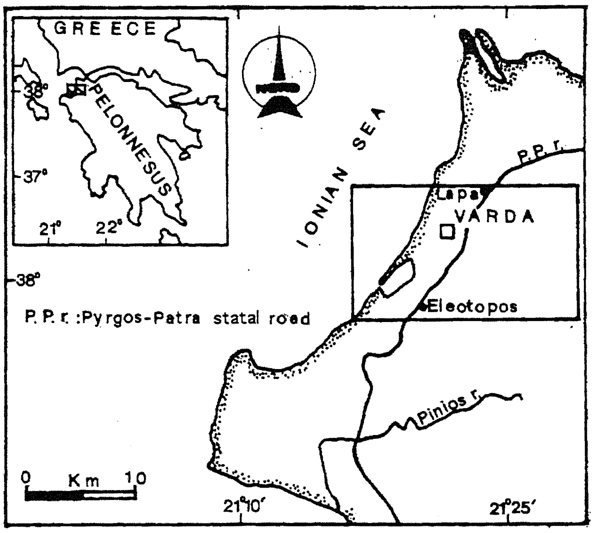

Fig. 1 - Area of geomorphological investigation, between Lapa and Eleotopos, NW Peloponesus, Greece.

Area oggetto dell'indagine geomorfologica, fra Lapa ed Eleotopos nel Peloponneso nord-occidentale, Grecia.

1. INTRODUCTION

The region between the villages of Lapa and Eleotopos (37°56', 21°14', 38°05', 21°30'), in northwestern Peloponnesus (Fig. 1) is characterized by a series of morphological units located between the Skolis mountain range and the sea (Fig. 2). These are:

a) a mountain front;

b) an ancient piedmont with a wide terrace;

c) a coastal plain with swamps; this plain is separated from the terrace by the Varda master fault.

The objectives of this paper are: a) the description of these morphological units in detail and b) the determination of the sequence of morphogenetic events through the geologic time on the basis of field data and published radiometric ages.

2. PREVIOUS STUDIES

There have been no geomorphologic studies in the studied area. Dufaure (1977) published a geomorphic map of Peloponnesus, which includes also the study

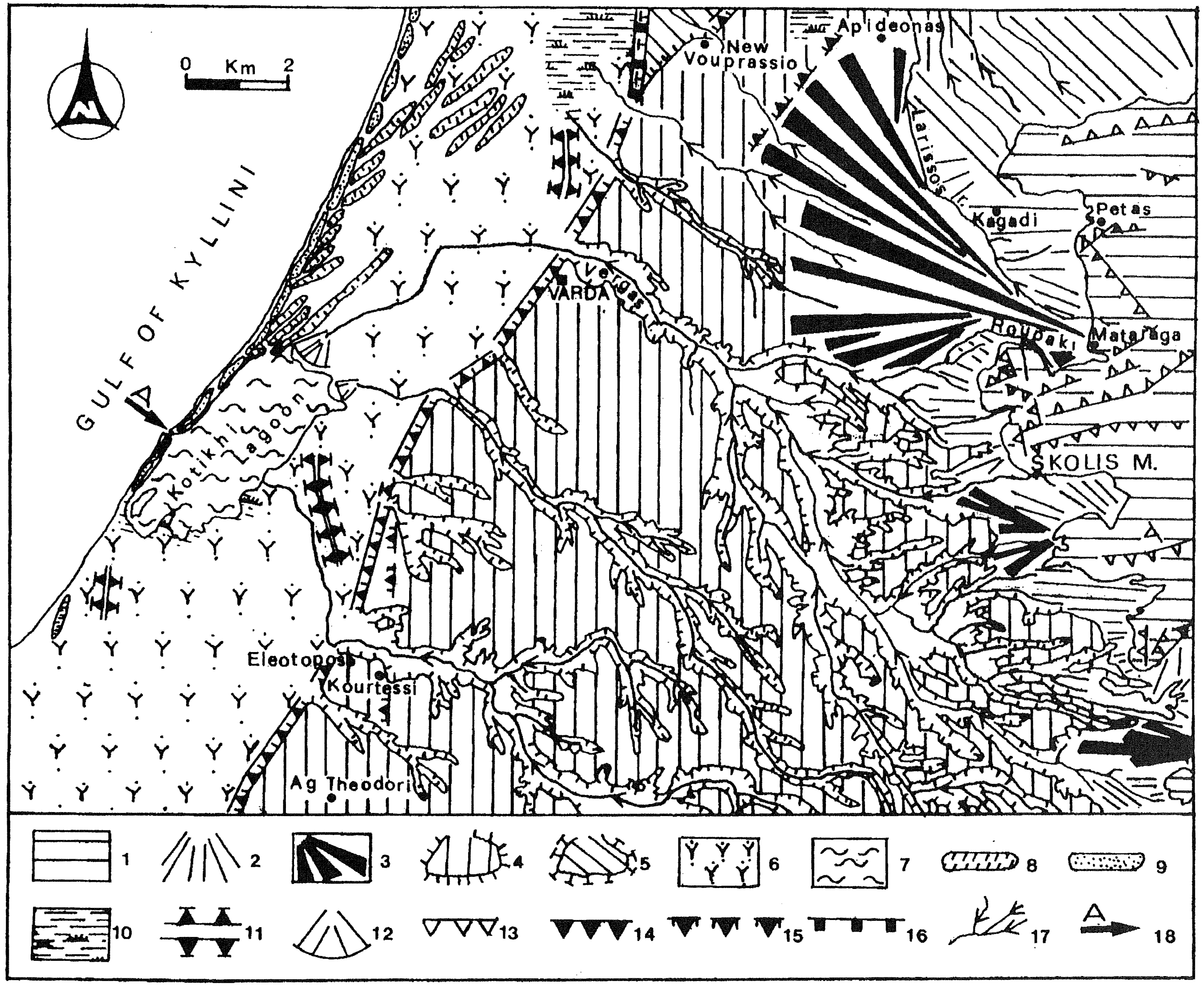

Fig. 2 - Schematic geomorphologic map of the study area: 1. Basement; 2. Pediments; 3. Alluvial fans; 4. Varda marine terrace; 5. Fluvial terrace of Vouprasio; 6. Undifferentiated coastal plain and flood basin; 7. Lagoon; 8. Beach ridges complex system; 9. Coastal dune; 10. Swamp; 11. Natural levees; 12. Recent delta; 13. Basement fault scarp; 14. Tyrrhenian Varda master fault scarp; 15. Probably fault scarp; 16. Vouprassio Holocene fault scarp; 17. River channel-stream; 18. Kotykhi lagoon inlet.

Carta geomorfologica schematica dell' area studiata: 1. Rocce del basamento; 2. Pedimenti; 3. Conoidi; 4. Terrazzo marino di Varda; 5. Terrazzo fluviale di Vuprassio; 6. Pianura alluvionale costiera; 7. Laguna; 8. Sistema di cordoni litorali; 9. Dune costiere; 10. Stagno; 11. Argini naturali; 12. Delta recenti; 13. Scarpata di faglia sulle rocce del basamento; 14. Scarpata principale di Varda, di età tirreniana; 15. Scarpata di faglia probabile. 16. Scarpata di faglia olocenica di Vuprassio; 17. Reticolo idrografico; 18. Bocca della laguna di Kotikhi.

area. Paraskevaides & Symeonides (1965) describe rock series from an adjacent area, considered Plio-Pleistocene in age. Tsoflias (1977) considered the terraced sequence in the study area, as marine Neogene and the overlying continental red sands as Pleistocene. Hageman (1977) recognized a marine to transitional series of Cenozoic age, composed of several cycles, south of the investigated area. The most recent of these cycles was considered by Hageman (1977) to be of Pleistocene age.

Stamatopoulos *et al.* (1989) showed that the terraced, marine to transitional sediments in the study area were middle to upper Pleistocene. Based on $^{230}Th/^{238}U$ isotopic data, these authors assigned the series to isotope substages 7.1, 5.3, and 5.5 (isotope substages after Martinson *et al.*, 1987). The oldest deposits of isotopic stage 7 are farthest removed from and at a higher elevation than the present day shoreline. The most recent deposits (isotopic stage 5) are closer to the sea and lower in elevation. These authors estimated that post-Tyrrhenian (stage 5) uplift of the area was less than 50 m.

According to Piper *et al.*, (1990) the areas of the Patras-Corinth gulf were occupied by a lake before 250 ka. These areas were subsequently submerged during interglaciation times, but emerged during marine regression with glaciation, corresponding to a fluviatile sedimentation.

3. GEOLOGIC AND GEOMORPHOLOGIC OBSERVATIONS

The investigated area is dominated by a vast terrace, the Varda terrace (4 in Fig. 2), which separates the coastal plain from the Skolis range. This terrace is 10 to 20 km wide and extends from 200 to 20 m a.s.l. without significant breaks in its transversal sections (Fig. 3).

The morphologic units mentioned in the introduction have been investigated in detail.

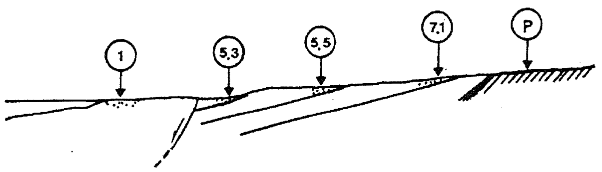

Fig. 3 - Schematic representation of the raised terraces in the east of Varda (based on Stamatopoulos, 1991). P = pediments; 1, 5.3, 5.5, and 7.1 are terraces from highstands in Holocene and isotopic substages 5.3, 5.5, and 7.1.

Rapresentazione schematica dei terrazzi sollevati a est di Varda (secondo Stamatopoulos, 1991). P = pedimenti, 1, 5.3, 5.5, 7.1 sono terrazzi corrispondenti ai periodi di alto dell'Olocene (1) ed ai substadi isotopici 5.3, 5.5, e 7.1.

3.1 The Mountain Front and its older piedmont

The Skolis mountains are built up by Gavrovos flysch (Richter, 1976; Richter *et al.*, 1978), containing alternating sandstones, marls and clays. The relief shows valleys and water divides with a dense stream network, in which the stream evolution can be recognized hierarchically. The relief is truncated on its seaward side by a fault scarp (1, 13 in Fig. 2), that was modified by receeding, parallel and linear erosion (Brancaccio *et al.*, 1978) and dissected transversally by stream erosion which developed triangular and trapezoid fractures. This fault scarp is connected to the terrace by concave profiles, which suggest an absence of recent movements between scarp and terrace. Therefore, the marginal faults of the Skolis massif should be considered essentially inactive, except in a very small area near the village of Petas, where some basal cliffs in the fault escarpment indicate recent movements.

Adjacent to the mountain front there is a terraced surface, which will be discussed in the next section. Between the terrace and the mountain front there is a wide pediment forming a connecting morphological unit which changes to an alluvial fan (2, 3 in Fig. 2) at the outlet of the principal mountain front valleys.

Alluvial fan sections observed during field work are related to the Larissos river fan. Its proximal and mid-fan zones lie between Mataraga and Kagadi, whereas the distal zone lies between Kagadi and Apideonas (Fig. 2). The Kagadi-Mataraga proximal facies consists of debris flow and overlying sheet flood deposits. The debris flow deposits observed at Roupaki (Fig. 2) consist of pebble to boulder size clasts in a sandy matrix. The sheet flood deposits consist of sand and silt with minor laterally persistent units of fine gravels. The presence of these two facies indicates either a semi-arid climatic environment (Bull, 1972, 1977; Schumm, 1977) or a marine lowstand, resulting in steeper overall gradients. The fining upwards proximal fan sequence should point to an active retrocession of the scarp-front (Heward,1978). A similar situation was described by Kontopoulos & Doutsos (1985) from nearby Pleistocenic alluvial fans on the north side of the Rion-Antirion graben. Low fan sediments are poorly exposed and have not been examined.

All alluvial fans sediments in the study area, show a typical red colour resulting not from alteration in situ but rather from transport of previously altered materials. It is also likely that during this transportation phase, the hematite responsible for the red colour was preserved over long distances (Kubiena, 1948).

3.2 Varda Terrace

Alluvial fan deposits rest unconformably partly on sands and silty sand of the terrace and partly on pediments; their succession has already been described by Stamatopoulos (1991). The contact surface between the terrace and the pediments is marked by an unconformity with a strongly calcite cemented sandy bed, 0.5 to 1 m thick, with common longitudinal concretions. The cementation of the sandy bed could be related to oscillations of the water table in a continental environment. The $CaCO_3$ enrichment may be due either to dissolution of fossil shells in sand and silts, according to the process described by Phleger (1969); or to differential dissolution of

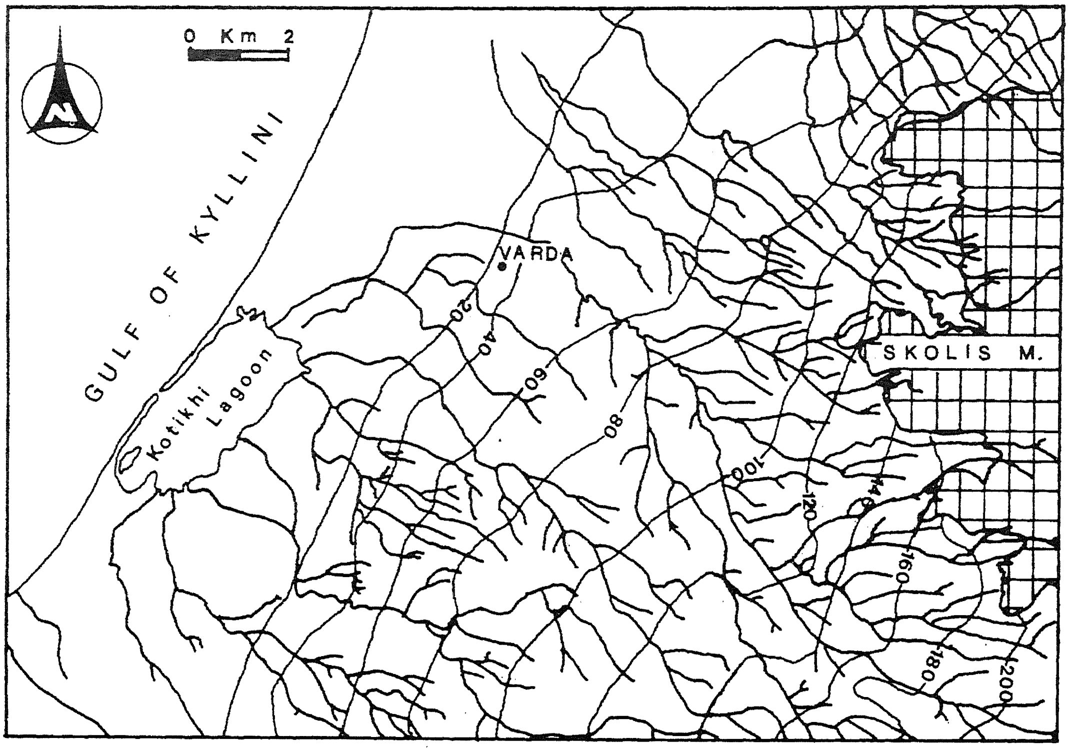

Fig. 4 - Trend surface map of the investigated area.
Carta della tendenza topografica dell'area studiata.

calcite-dominated sediment in a subaerial environment, as suggested by the presence of the concretions (Collinson & Thompson, 1982). In contrast, the $CaCO_3$ precipitation could be connected to evaporation of phreatic water in capillary rise during sub-aerial exposure in a sub-arid climate.

The terraced deposits series (Stamatopoulos *et al.*, 1989) is composed of an alternation of sands, silts and clays of lagoonal and shallow marine origin in which three cycles can be recognized. The first belongs to isotopic substage 7.1, the second which pinches out on the first, to substage 5.5 and the third to substage 5.3 (Fig. 3). In some areas these are covered by a veneer of continental sands. The terrace surface is incised by a dense hydrographic network and dips towards the sea with a uniform slope (Fig. 4).

In the trend-surface map obtained by eliminating the sinuosity of contour lines due to erosion by incised rivers, the distance between contour lines,"in a longitudinal outline", is almost uniform but decreases rapidly between the 40 m and 20 m contours at the south-east end of the Varda terrace (Fig. 4). This suggests a well preserved rectilinear fault scarp, the Varda master fault scarp, that is the lower limit of the marine terrace (14 in Fig. 2; "c" in Fig. 5; "f" in Fig. 6). Many rivers flowing on the terrace cut trapezoidal facets on the fault scarp ("d" in Fig. 5) while rivers that come close to the escarpment flow parallel to it (A in Fig. 5). This anomalous course of rivers in the south end of the Varda fault scarp suggests that the hanging wall of the Varda fault has a back tilting character which itself define a listric geometry of fault (A in Fig. 5). A similar situation can be noticed in Apideonas (Fig. 2) where, at the bottom of an existing small fault scarp (g in Fig. 6) with a morphologic offset of less than one meter, an area marked by a system of swamps due to the upstream tilting of the hanging wall can be observed (10 in Fig 2; "d" in Fig. 6). In other situations, such as at Kourtessi, a splitting of the fault scarp can be found ("e" in Fig, 5). It is possible that such splitting before the creation of the Varda master fault changed the relative base level for the upstream rivers for a certain period. This interpretation is supported by the presence of a second terrace in the valley upstream. It is embedded in the first one and it is not referred to in the geomorphologic map because of its small size.

3.3. The Terrace of Vouprassio

The Varda fault scarp is oriented N45°E (14 in Fig. 2). At its foot, near New Vouprassio, a minor terraced surface (5 in Fig. 2) between 20 and 10 m a.s.l. is bound W of New Vouprassio by another small fault (16 in Fig. 2; "h" in Fig. 6) oriented N10°E and overlooking the present coastal plain. This small terrace consists of continental deposits belonging to alluvial fans made by braided rivers incising the Varda fault scarp (3 in Fig. 6). These deposits have about 6 m exposed thickness. Similar river deposits are found in other areas at the foot of the Varda fault scarp. The New Vouprasio continental deposits outcroping at a big quarry a few meters west of the Patras-Pirgos state road (5 in Fig. 2), near New Vouprassio contain a buried black soil, 1.75 m under the ground, a sample of which was submitted for ^{14}C radiometric analysis using the Belluomini method (1974).

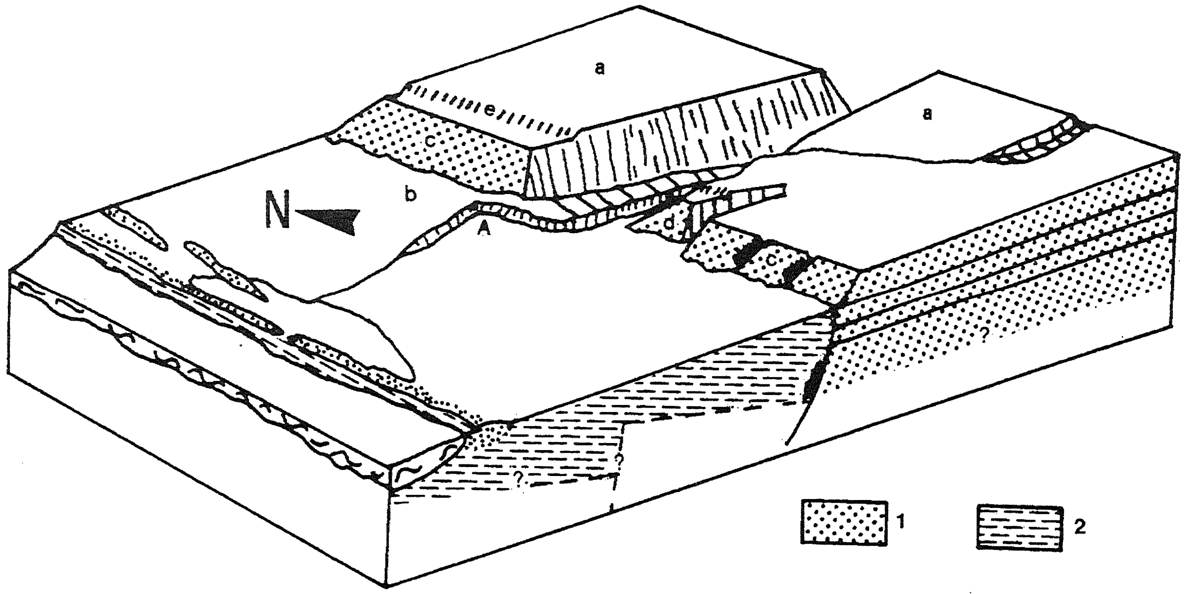

Fig. 5 - Block diagram of the geomorphological events in the Kourtessi area. a: Marine terrace; b: Coastal plain; c: Varda master fault scarp; d: Trapezoidal facets of the Varda fault scarp; e: Fault scarp splitting; A: Anomalous course of a river, parallel to the fault scarp;1:Varda terrace sediments; 2: Coastal plain sediments.

Blocco diagramma schematico delle forme del rilievo nell'area di Kurtessi. a: Terrazzo marino; b: Piana costiera; c: Scarpata principale di Varda; d: Faccette trapezoidiche della scarpata di faglia di Varda; e: Scarpata di faglia di dimensioni minori, ripetizione della prima; A: Tratto anomalo del fiume, parallelo alla scarpata di faglia; 1: Sedimenti del terrazzo di Varda, 2: Sedimenti della Piana costiera.

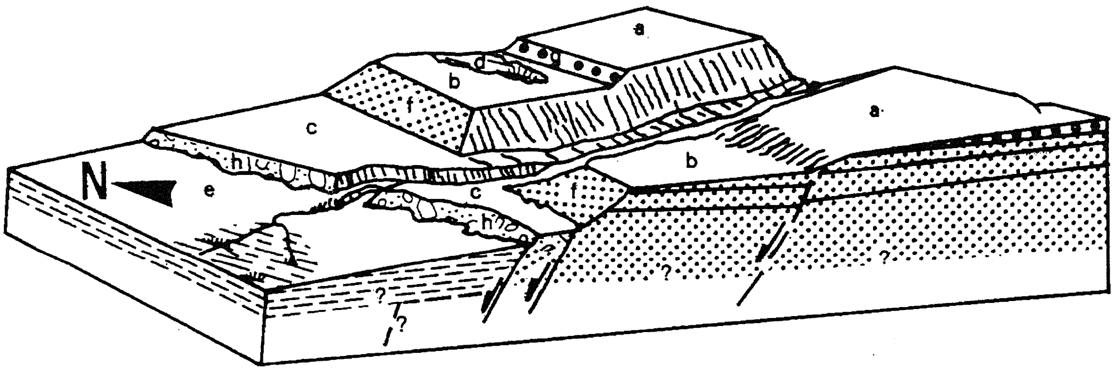

Fig. 6 - Block diagram of the geomorphological events in the Vouprassio area. a: Riolos-Mataraga fan; b: Marine terrace; c: Vouprassio alluvial terrace; d: Apideonas Marshes; e: Coastal plain; f: Varda master fault scarp; g: Apideonas fault scarp; h: Vouprassio fault scarp; 1: Varda terrace sediments; 2: Coastal plain sediments; 3: Vouprassio alluvial terrace sediments.

Blocco diagramma schematico delle forme del rilievo nell'area di Vuprassio. a: Conoide di Riolos-Mataraga; b: Terrazzo marino; c: Terrazzo alluvionale di Vuprassio; d: Stagni di Apideona; e: Piana costiera; f: Scarpata di faglia pricipale di Varda; g: Scarpata di faglia di Apideona; h: Scarpata di faglia di Vuprassio; 1: Depositi del terrazzo di Varda; 2: Depositi della Piana costiera; 3: Depositi del terrazzo alluvionale di Vuprassio.

Results give a date of 290 ±70 years B.P. This corresponds to the recent alluvial phase recorded in Greece (Raphael, 1973; 1978). Thus the small fault cutting New Vouprassio terrace deposits appears to have been recently active.

3.4. The Coastal Plain

The coastal plain occupies an area of nearly 80 km^2 west of the Patras-Pirgos state road and is defined to the east by the Varda fault (6, in Fig. 2). The plain, with a very low gradient, is cut by a number of rivers (Fig. 4) that are incised a few meters below the plain. The origin of such incision is unclear and could be connected to climatic variations or to changes of the sea-coastal relative level (tectonic or glacio-eustatic), or to anthropogenic factors (Raphael, 1973; 1978). The rivers are narrow and shallow, flow ephemerally and, during floods, they produce natural levees, swamps and small ephemeral lakes on the coastal plain (10, 11 in Fig. 2). The coastal plain includes the Kotykhi lagoon (7 in Fig. 2), 20 km^2 in area and nearly 3 m deep. It is separated from the sea by a sand barrier where an inlet is opened (18 in Fig. 2). According to Raphael (1973) the inlet formed during the last 150 years At the edge of the lagoon, small river mouths have created a number of deltas with fine-grained sediments (12 in Fig. 2). North of Kotykhi is a crescentic series of beach ridges (8 in Fig. 2) that show the presence of an ancient large river mouth close to the present inlet. Progradation must have taken place since sea level reached its present level approximately 6000 years B.P. Beach ridges (8 in Fig. 2) are currently covered by eolian dunes (9 in Fig. 2). The present coastal process in the coastal plain is one of erosion (Raphael, 1978).

4. DISCUSSION

Using available absolute chronologic data, the age of several morphologic units can be determined. The pinch out of marine deposits of isotopic stage 5, in comparison to those of isotopic stage 7, allow the main terraced surface (Varda terrace) to be ascribed to the Tyrrhenian, and represents a marine regression surface. The fact that the age of the marine deposits increases with the distance from the coast and with altidute (Fig. 3) clearly indicates that tectonic uplift occured in the area during Tyrrhenian times. Alluvial fan and glacis deposits lying on the marine terrace are connected to a following phase which can be related to the first climatic deterioration in the late Pleistocene (Würm anaglacial). The granulometric and textural features of the deposits are consistent with a strong soil erosion environment such as that produced during the last glaciation. Alluvial fans and glacis are not deeply embanked in the incisions cutting the terraced surface but they are altitudinally related to it. This in-dicates that the regressive erosion phase due to late Pleistocene (Würm) glacio-eustatic regression (or tectonic uplifting) had not yet reached the upper part of the Varda terrace. A remarkable post-Tyrrhenian tectonic phase, uplifted the Varda terrace nearly +6 meters above datum (the likely sea level during the Tyrrhenian) up to its present level of 20÷200 m above datum. It faulted the sediments (Varda fault), thus lowering the hanging wall block with a likely rotation (suggesting a listric geometry). Tectonic activity carried on during Holocene so that the same river sediments belonging to the Vouprassio terrace, of historical age, are faulted .

The coastal plain deposits are of Holocene age (Raphael, 1978) and are connected to the Flandrian glacio-eustatic transgression. Progradation of the plain with successive beach-ridges belongs to Roman times (Raphael, 1978).

5. THE SUCCESSION OF MORPHOGENETIC EVENTS

A sequence of morphogenetic events is proposed on the basis of field data and published radiometric ages:

1. The region was involved in a stretching tectonic pattern which lowered the flysch area towards the sea while uplifting the entire region towards inland. A fault scarp was created.
2. As a result of this tectonism, which took place before isotopic stage 7 (*i. e.,* middle Pleistocene or earlier), the sea penetrated up to the present mountain front. It created a wide bay, which developed a number of lagoonal phases during the Tyrrhenian.
3. During the late Pleistocene there was a glacio-eustatic movement and probably a tectonic marine regression. Marine deposits belonging to the Tyrrhenian are covered in some places by continental sediments that decrease in thickness from the alluvial fans and pediment deposits towards the present coastline. The resulting morphology is typical of an alluvial plain extend-ing from the mountain front to the sea. The shore was in an unknown position, probably seaward of the present position.
4. The post-Tyrrhenian creation of the Varda master fault lowered the north-west area of the terrace under Tyrrhenian sea level. This terraced area is nowdays at the present altitude and has begun to be deeply reincided by streams. The deepening of the ancient valley bottoms produced minor fluvial terraces. Later a tectonic phase splitting the Varda fault (*e. g.* Kourtessi area) displaced the terrace towards the sea, lowering it by some meters. It started a new erosional phase responsible for the formation of wide and shallow valleys on the terrace.
5. During the Holocene, alluvial deposits were formed in front of the Varda fault scarp (Vouprassio terrace).
6. Coastal progradation through advance of beach ridges established the present coastal plain,which is now being re-eroded.

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