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EVIDENCE OF TECTONIC INFLUENCE ON DRAINAGE EVOLUTION IN AN UPLIFTING AREA: THE CASE OF NORTHERN SILA (CALABRIA, ITALY)

ABSTRACT: MOLIN P., FUBELLI G. & DRAMIS F., *Evidence of tectonic influence on drainage evolution in an uplifting area: the case of northern Sila (Calabria, Italy)*. (IT ISSN 0391-9838, 2012).

The Sila Massif (Calabria, southern Italy) is a high-standing plateau with a rolling upland surface lying between 1000 and 1900 m. It is underlain by magmatic and metamorphic rocks thrusted over Mesozoic carbonate and terrigenous units. The Sila Massif is surrounded by low-standing extensional basins, filled with several upper Tortonian to Holocene marine and fluvial deposits. Since the end of the early Pleistocene, the Sila Massif has been uplifted regionally as indicated by deeply incised river valleys and flights of marine terraces. The low-relief Sila upland surface is the remnants of a pre-uplifted landscape developed during a long time of stable base level. Our study examines the tectonic geomorphology of an area extending from the northern flank of the massif to its interiors including the Cecita Lake. We focused on the general topographic metrics, drainage patterns, and river long profiles, based on field surveys and aerial-photo interpretation. Our goal was to investigate the local tectonic constrains on the evolution of northern Sila drainage network in the context of the Calabrian Arc uplift. Our results indicate that the drainage evolution has been strongly controlled primarily by local tectonics and secondarily by regional uplift. In particular, we suggest that the northward continuation of the informally-named Cecita Lake Fault has recently reorganized the northern Sila drainage by west-side down subsidence of the hanging wall.

KEY WORDS: Uplift, Tectonics, Drainage network, Sila Massif, Italy.

RIASSUNTO: MOLIN P., FUBELLI G. & DRAMIS F., *Evidenze dell'influenza della tettonica sull'evoluzione del drenaggio in un'area in sollevamento: il caso della Sila settentrionale (Calabria)*. (IT ISSN 0391-9838, 2012).

La Sila (Calabria, Italia meridionale) è un massiccio caratterizzato da un altopiano dolcemente ondulato a circa 1000-1900 m di quota. Il Massiccio della Sila, costituito da rocce cristalline e metamorfiche sovrascorse su carbonati e depositi silico-clastici mesozoici, è circondato da bacini estensionali. In questi affiorano depositi marini e continentali di età variabile dal Tortoniano all'Olocene. Dalla fine del Pleistocene inferiore, la Sila è stata interessata da un sollevamento regionale, come testimoniato dalle valli fluviali profondamente incise e dai terrazzi marini. La superficie a basso rilievo locale ubicata sull'altopiano silano rappresenta ciò che resta di un antico paesaggio sviluppatosi prima del sollevamento quaternario, in condizioni di relativa stabilità del livello di base. È stata esaminata la morfotettonica di un'area che si estende dalle pendici settentrionali del massiccio fino al suo interno, dove si trova il Lago Cecita. Lo studio si è focalizzato su analisi morfometriche della topografia generale e dei bacini di drenaggio, su attività di terreno e fotointerpretazione. Il fine è di indagare le evidenze dell'influenza della tettonica locale sull'evoluzione del sistema idrografico della Sila settentrionale, nel contesto del sollevamento dell'Arco Calabro. I risultati indicano che, sebbene il sollevamento regionale abbia indotto una forte incisione, l'evoluzione del drenaggio è stata fortemente condizionata dalla tettonica locale. In particolare, viene proposto di estendere verso nord la Faglia del Lago Cecita, considerata in letteratura attiva nel Quaternario e caratterizzata da microsismicità. Questo sistema ha riorganizzato il drenaggio della Sila settentrionale, abbassandone la porzione occidentale.

TERMINI CHIAVE: Sollevamento, Tettonica, Reticolo idrografico, Massiccio della Sila.

INTRODUCTION

Fluvial erosion is one of the major agents of landscape evolution. Indeed, outside of glaciated regions, rivers are responsible for shaping uplifted terrain into valley networks and generating the relief that drives gravitational transport processes (Tucker & Whipple, 2002). Rivers are also particularly sensitive to tectonics because of the gradient changes imposed by such perturbation (Holbrook & Schumm, 1999). So the study of topography, including drainage patterns and stream longitudinal profiles, could represent a strong tool to investigate the tectonics influence on landscape evolution.

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In this paper we have analysed the topography of the northern portion of the Sila Massif (Calabria, southern Italy), a high-standing plateau surrounded by flanks strongly dissected by streams that are competing to incorporate into Sila interior. This fluvial incision has been induced by regional uplift, coupled with the Quaternary climate changes, whereas local tectonic structures ruled the drainage pattern organization. In detail, our study examines the tectonic geomorphology of northern Sila, extending from the northern flank of the massif to its interiors including the Cecita Lake. We focused on the general topographic metrics, drainage patterns, river longitudinal profiles based on field surveys and air-photo interpretation. Our goal is to study the northernmost portion of Sila more in detail with respect to Molin et al. (2004) that examined the massif at a regional scale. Indeed, we focused our investigation on the local tectonic influence on the evolution of northern Sila drainage network in the context of the Calabrian arc uplift. Our results indicate that the drainage evolution has been strongly controlled primarily by local tectonics and secondarily by regional uplift. In particular, we suggest a northward continuation of the NNW-SSE extensional structure named Cecita Lake Fault (Guerra & *alii*, 2000; Moretti, 2000; Galli & Bosi, 2004). This tectonic system reorganized the northern Sila drainage by west-side down subsidence of the hanging wall. The Cecita Lake Fault is considered to be active in the Quaternary by offset stratigraphy as well as by proximal microseismic activity (Guerra & *alii*, 2000; Moretti, 2000; Galli & Bosi, 2004).

GEOLOGICAL AND TOPOGRAPHIC SETTING

The northern Sila is a portion of a massif, characterized by a high-standing plateau with a rolling upland lying between 1000 and 1900 m a. s. l., a depressed interior, and gently raised edges (fig. 1). A natural lake in the same location of the modern Cecita Lake reservoir occupied the centre of the plateau during the Quaternary (Henderson, 1970; Dramis & *alii*, 1990; Amanti & *alii*, 2002; Galli & Bosi, 2004). The high-standing plateau is surrounded by flank deeply dissected by streams that flow to the Ionian Sea or are tributaries of the Crati River (fig. 1).

The northern Sila is underlain by magmatic and metamorphic rocks thrust over Mesozoic carbonate and sin-orogenic terrigenous units (Ogniben, 1973; Amodio-Morelli & *alii*, 1976; Dietrich, 1976; Lanzafame & *alii*, 1979; Critelli, 1990) (fig. 2). The metamorphic and magmatic rocks are generally deeply weathered to a saprolite several meters deep (Le Pera & Sorriso-Valvo, 2000). The Sila Massif is separated from the surrounding landscape by large extensional faults (Lanzafame & Tortorici, 1981; Ciaranfi & *alii*, 1983; Moussat & *alii*, 1986; Knott & Turco, 1991; Moretti, 1993; Sorriso-Valvo, 1993; Tortorici & *alii*, 1995) that locally form steep escarpments featured by triangular facets. The low-standing extensional basins around Sila are filled by several upper Tortonian to Holocene depositional sequences composed of prevalently poorly consolidated marine, deltaic, and fluvial conglomerate, sand, and clay (Vezzani, 1968; Ogniben, 1973; Lanzafame & Tortorici, 1981; Colella & *alii*, 1987; Critelli, 1990; Colella, 1995; Tortorici & *alii*, 1995).

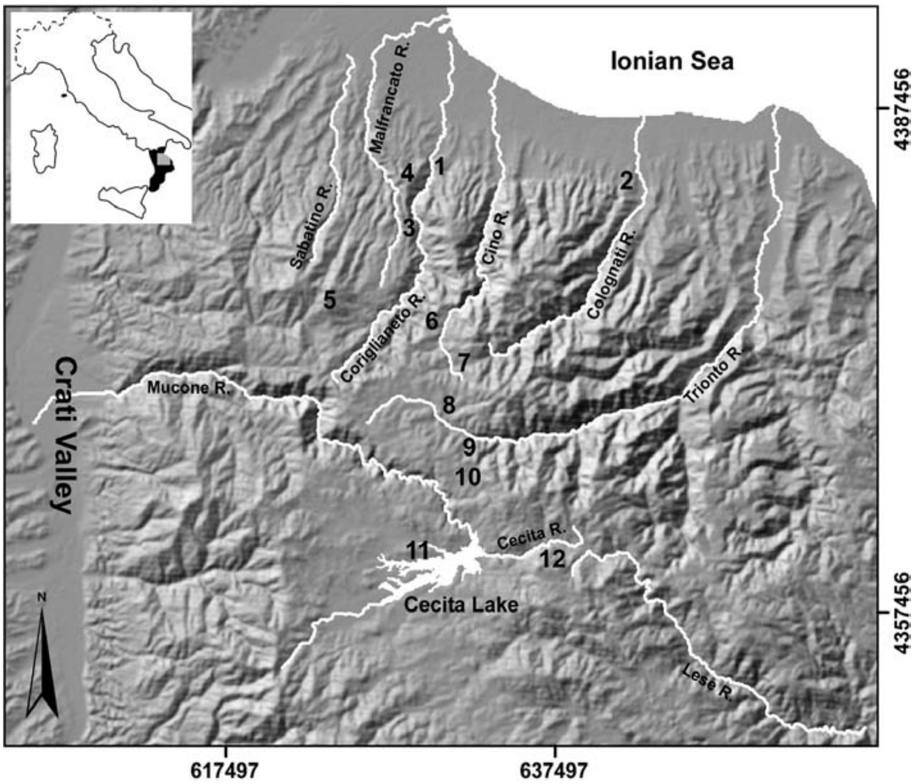


FIG. 1 - Shaded relief of the study area including an inset of its location in the Italian peninsula and the study streams; 1) Corigliano village; 2) Rossano village; 3) Foresta village; 4) Serra Palazzo; 5) Serra Crista d'Acri; 6) Baraccone village; 7) Case Bonis and Cino/Coriglianeto rivers windgap; 8) I Cotri and Campo Rotondo; 9) Difesella; 10) Pantano small basin; 11) Serra della Giumenta; 12) Cecita/Lese rivers windgap.

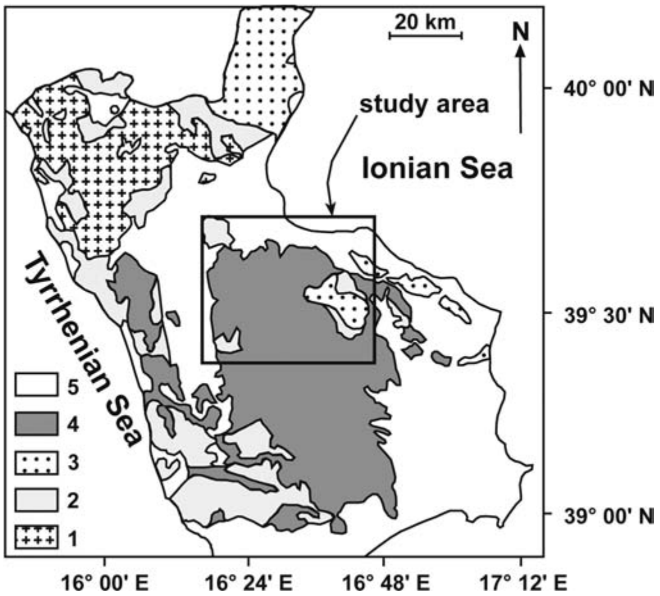


FIG. 2 - Simplified geologic map of Northern Calabria and location of the study area: 1) Apennine carbonate units; 2) low-grade metamorphic units and ophiolites; 3) sedimentary, mainly silico-clastic type units; 4) intrusive and intermediate and high-grade metamorphic rocks of crustal Alpine units; 5) Miocene to Holocene sedimentary autochthonous units (after Sorriso-Valvo, 1993).

In detail, in the study area, upper Pliocene - lower Pleistocene deposits («Ciclo suprapliocenico-pleistocenico»; Vezzani, 1968) unconformably overlay a Miocene succession and underlie the middle-upper Pleistocene sand and conglomerate (Roda, 1964; Vezzani, 1968; Ogniben, 1973; Critelli, 1990). The «Ciclo suprapliocenico-pleistocenico» (Vezzani, 1968) consists of a transgressive/regressive cycle, testified by the deposition of fossiliferous beach sandstone grading upward into grey clay, which passes upward into conglomerate and sand. In the Mirto area, the upper portion of the clayey deposits has been referred to middle Pleistocene by fission-track dating of an ash layer (Bigazzi & Carobene, 2004). Since the end of early Pleistocene, similarly to the rest of Italian peninsula, the Sila Massif has been uplifted regionally (Vezzani, 1968; Tortorici, 1980, Tortorici, 1981; Ciaranfi & *alii*, 1983; Lanzafame & Tortorici, 1981; Boccaletti & *alii*, 1984; Colella & *alii*, 1987; Moretti, 1993; Tortorici & *alii*, 1995; Moretti & Guerra, 1997). In middle and late Pleistocene, the interaction between regional uplift and climate variations originated a well developed staircase of marine and marine to continental terraces and deeply incised fluvial valleys (Tortorici, 1980; Lanzafame & Tortorici, 1981; Carobene & *alii*, 1986; Colella & *alii*, 1987; Gliozzi, 1988; Carobene & *alii*, 1989; Carobene & Dai Prà, 1990; Palmentola & *alii*, 1990; Moretti, 1993; Cucci & Cinti, 1998; Mauz & Hassler, 2000; Molin & *alii*, 2002; Carobene, 2003; Robustelli & *alii*, 2009). A low relief surface located on Sila Massif summit area is the remnant of a pre-uplifted landscape developed during a long time of stable base level condition (Dramis & *alii*, 1990; Molin & *alii*, 2004; Olivetti & *alii*, 2012).

In the study area two active fault systems are present: the Rossano-Corigliano System, located at the Sila mountain front, and the Cecita Lake Fault (Guerra & *alii*, 2000; Moretti, 2000; Galli & Bosi, 2004), that cut across the Sila Massif. A strong earthquake in 1836 ($M_e = 6.2$; Working Group CPTI, 1999; $I_{max} = X$, Moretti, 2000) has been referred to the Rossano-Corigliano System, that is composed by several faults oriented E-W and NW-SE (Moretti, 2000). The Cecita Lake Fault displaces Pleistocene lacustrine clay of 150-170 m and slope deposits, but up to now it is considered historically silent (Moretti, 2000; Galli & Bosi, 2004). Conversely the instrumental seismicity indicates microseismic activity in the Sila interior close to this fault (Guerra & *alii*, 2000).

METHODS

We performed a geological and morphological survey focusing mainly on the stratigraphical analysis of superficial deposits. Our base work maps are IGM 1:25,000 Calabria topo-sheets included in the 1:100,000 topo-sheets numbered 229 and 230. Mapping has been supported by air-photo interpretation of several strips at ca. 1:33,000 scale, taken in 1984.

To investigate topography and drainage pattern of northern Sila, our main data source is the 90 m pixel size SRTM DEM. Since rivers are very sensitive to tectonics, to point out possible perturbation of channel slope we extracted nine stream longitudinal profiles sampling the topography every 100 m along the main trunk and plotting the data on a distance vs. elevation diagram. Deviations from the equilibrium concave up shape record base level and/or climate changes, and tectonic and rock-type perturbations.

To better describe the topographic setting and to provide an idea of the fluvial incision of the study area we elaborated four swath cross sections and two maps showing the slope pattern and the local relief. To generate the swath profiles we sampled the DEM at regular interval of 250 m along five 500 m spaced adjacent cross sections and then we averaged out the maximum, minimum and mean topography. The trend of the maximum and minimum elevation represents respectively the average pattern of mountain peaks and valley bottoms. We have also calculated the residual among these two to show the variation of the local relief in the study area. Three swath profiles are oriented E-W and cross the entire study area, whereas one, trending NE-SW, cuts across the northern flank of the Sila Massif.

The slope map has been elaborated using the ArcGIS extension Spatial Analyst. We have chosen ten ranges (eight equally spaced and two including higher, but rare values) according to the slope value frequency.

The local relief map shows the residual between two surfaces that describe the general configuration of peak and valley bottom elevations. Both of them have been smoothed in frequency domain using a low pass filter to attenuate the topography wave-length with frequencies higher than 3 km that is the average main valley spacing resolvable by the DEM resolution. Subtracting arithmetically the two surfaces, we obtained the local relief map that reveals where the topography is more deeply incised by streams.

RESULTS

In the study area, the Sila interior, characterised by a gently rolling upland surface, is drained by two major streams, the Trionto and the Mucone rivers (fig. 3). The Trionto River, which upper course has an E-W direction, traverses the north-eastern plateau edge and flows northward to the Ionian Sea. The Mucone River is a tributary of the Crati River that deeply incises the plateau and the Sila western flank downstream of the dam of Cecita reservoir, located at around 1100 m of elevation. The Mucone River headwaters flow SW-NE, but the main trunk changes direction abruptly to a NW-SE trend at the Cecita Lake dam. All other streams draining the study area either flow into Cecita Lake or are external to the plateau, failing to breach its edges. The headwaters of several streams (for example Cino, Colognati, Cecita, and Lese rivers) flow in wide, poorly incised valleys that appear developed in the same base level conditions of the upland surface. These valleys are often crossed by drainage divides forming windgaps between competing rivers. In general, the upper and middle portions of the external drainages are bedrock channels deeply incised into the Sila flanks and forming narrow valleys with very steep slopes. Where the streams reach the hilly piedmont located at the foot of the northern flank and the adjacent coastal plain, their channels become braided and the valleys wide and shallow.

The study area appears affected by several lineaments diversely oriented (fig. 3). To the north, some segments of the Rossano-Corigliano Fault System separate Sila from the hilly coastal belt. More to the south, E-W lineaments affect the portion of Sila flank located west of Coriglianeto River valley. Three of them are more extended: the one located close to the Foresta village (figs. 1 and 3), that herein will be called Foresta Line, corresponds to an old through-shaped small valley presently dissected by modern SW-NE drainages; two are located between Serra Crista d'Acri and the Mucone River valley, bounding a relatively depressed area. All these lineaments are interrupted by a NNW-SSE one that follows the Coriglianeto River valley and becomes NW-SE when it bounds the southern slope of Serra Palazzo (figs. 1 and 3). In our opinion, this lineament is a northernward continuation of the Cecita Lake Fault. All along this fault system there are several geologic and morphologic features: a small sedimentary basin along Cino River, a windgap between Cino and Colognati drainages and terraced landforms, terraces along the upper course of Trionto River, the small basin of Pantano, the Pleistocene Cecita Lake deposits, and a windgap between Cecita and Lese drainages (figs. 1 and 3). So to investigate the tectonic influence on drainage evolution in northern Sila, we surveyed the intersection area between the Foresta Line and the Coriglianeto River present valley, and the landforms and the relative post-orogen deposits along the Cecita Lake Fault.

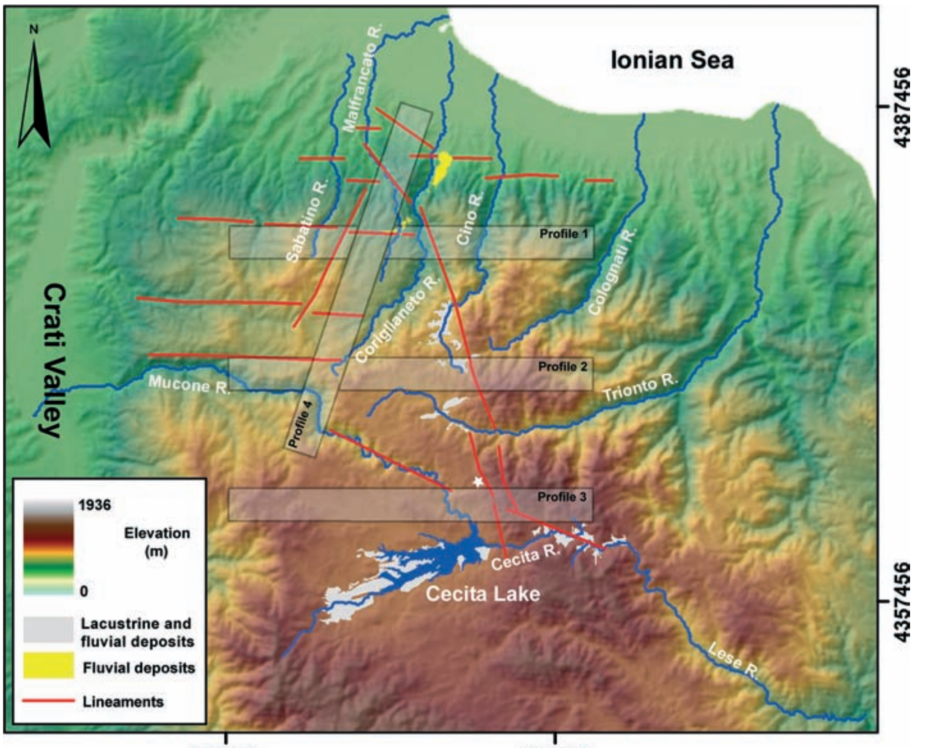


FIG. 3 - Topography of the study area and location of surveyed deposits, study streams, swath profiles (light grey boxes), and tectonic lineaments. The white star indicates the small basin of Pantano.

The Corigliano village is partially set on a sedimentary body, roughly elongated N-S, ca. 2 km in length, and bound to the west by the Coriglianeto River incision (see fig. 3 for location). It crops out from an elevation of around 300 m down to 100 m and it reaches locally a thickness of 60 m. It is constituted mainly by conglomerate and secondary by sand. Generally the granulometry decreases from south to north, i.e. from the higher elevation towards the coastal belt. The clasts, that could reach 40 cm in diameter, are rounded, but are subangular in the more apical portion of the sedimentary body. They are often embricated indicating in general a northward flow. The Corigliano sedimentary body is stratified and the layers dip to the north. The facies is fluvial in the apical part, but it becomes typical of fan-delta to the north. Along the downstream right of the Coriglianeto River valley, at an elevation of 300-350 m, few outcrops of the same fluvial conglomerate (with subangular clasts in sandy matrix) are located. In the downstream left of the Coriglianeto River valley, again very similar fluvial conglomerate crops out close to the Foresta village (see figs. 1 and 3 for location; fig. 4). Here the sedimentary body is several meters thick and appears elongated E-W, but it curves to a NE-SW trend close to Foresta and the interfluve between Coriglianeto and Malfrancato rivers (fig. 3). Both Corigliano and Foresta deposits are Pliocene-Lower Pleistocene in age according to Marchetti & *alii* (1970d, 1970e) and to the interfingered boundary between the fan deposits and the basal marine sand of the «Ciclo suprapliocenico-pleistocenico» (Vezzani, 1968).

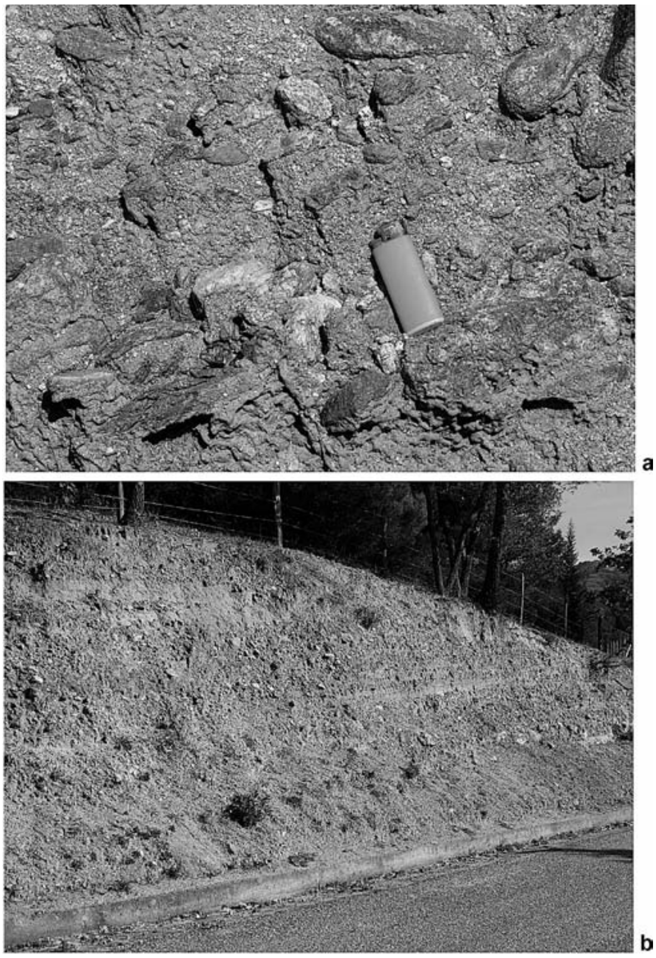


FIG. 4 - a) Detail of the fluvial conglomerate cropping out in the neighbourhood of Foresta village: the subangular clasts in sandy matrix are embricated and indicate a NE flow direction; b) road cut showing the Foresta sedimentary body depositional architecture: the channels are sheet type and several sandy layers are intercalated with conglomerates.

Along the upper course of Cino River, close to the Baraccone village (fig. 1), the valley widens with a 15 m wide alluvial plain filled by sub-angular conglomerate and sand (fig. 3). Here it contains two orders of terraces Quaternary in age (Marchetti & *alii*, 1970d): the older one shows no outcrop, conversely a section located in the younger order terrace shows a 8 m thick sequence. This is made of sand, sandy clay and sub-angular conglomerate. The downstream edge of the terrace corresponds to an abrupt narrowing of the valley, exactly where the northward continuation of the Cecita Lake Fault crosses the river (fig. 5). More headward, the Cino River flows in a wide low-gradient valley, along which a windgap between Cino and Colognati rivers is located (Case Bonis, fig. 1). There two orders of terraces (Quaternary in age; Marchetti & *alii*, 1970c) are also present but only the older one shows good enough sections

FIG. 5 - Strike-slip fault associated to the northward continuation of the Cecita Lake Fault cutting across the Cino River valley close to Baraccone village.

where fluvial and debris flow sediments crop out. In detail, the base of this continental sequence is characterised by a matrix-supported deposits, with heterometric clasts, from microconglomerate to boulder in size. It is overlaid by subangular clast-supported conglomerate, with coarse sandy matrix and levels of conglomerate with open-work structure. The latters are locally interfingered with sand and sandy clay levels. The flow paleodirection is to the NW. Under microscope observation, the fine portion of these deposits resulted barren and constituted by mica, quartz, and feldspar angular clasts. The abundance of mica indicates that the clast source (i.e. hillslope) is very close.

In the upper course of Trionto River, upstream of Difesella, fluvial deposits outcrop at I Cotri and Campo Rotondo (fig. 1). Three wide sections show a 15 m thick sequence (fig. 6a). From bottom to top, this is made up of heterometric, chaotic coarse gravels with abundant sandy matrix, passing upward to sandy and sandy-clayey parallel and cross-stratification levels. At the top a well-rounded granite conglomerate generates a wide and well-preserved terrace surface. Channel depositional architecture is often recognizable. A locally organic carbon layer has been dated by Radiocarbon method giving this sequence an age of 31.000 yr B.P. (Calderoni & *alii*, 1989). More downstream, close to Difesella (fig. 1), a 3 m wide section shows well cemented clay interbedded with sandy layers, overlaid by conglomerates in sandy matrix (fig. 6b). This deposit has been referred to Quaternary by Marchetti & *alii* (1970c). Microscope observations testifies flow micro-structures. X-ray diffractometer analysis (by courtesy of Sergio Lo Mastro) on two samples shows the presence of quartz, calcite, K-feldspar, plagioclase, mica, chlorite, portlandite, and trace of gypsum and amphibole. River terraces suddenly disappear downstream of Difesella, in correspondence of a segment of Cecita Lake Fault (fig. 3).

The area including the Cecita Lake is filled with terraced Quaternary deposits, morphologically entrenched at lower elevations within the older dissected landforms (Marchetti & *alii*, 1970b; Dramis & *alii*, 1990; Sorriso-Valvo, 1993; Ferrini & Moretti, 1997; Matano & Di Nocera, 1999; Caruso & *alii*, 2000). These deposits, constituted by conglomerate, sand and clay, have been referred to fluvial and lacustrine facies (Scarciglia & *alii*, 2005). Beach rock surface has been detected in Serra della Giumenta peninsula (see fig. 1 for location; fig. 7). A sample collected here

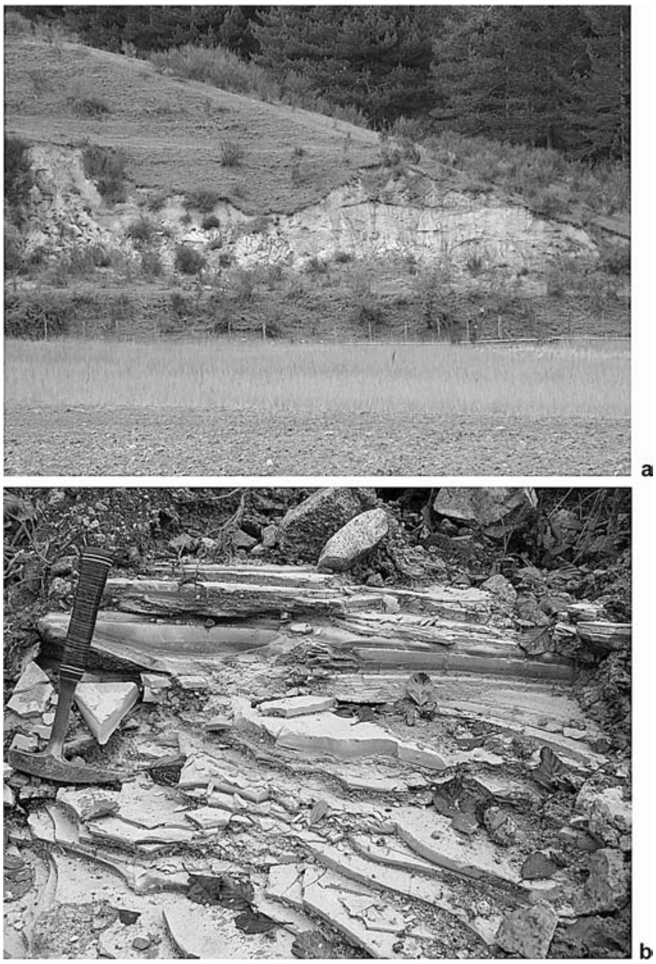


FIG. 6 - a) the outcrop of Campo Rotondo showing a part of 15 m thick sequence of fluvial deposits: the darker layer, close to the top, has been dated by Radiocarbon method to 31,000 yr B.P. (Calderoni & *alii*, 1989); b) detail of the well cemented clay interbedded with sandy layers, outcropping at Difesella.

FIG. 7 - Beach rock at Serra della Giumenta peninsula (Cecita Lake).

has been analysed under microscope observation. Its finer portion resulted to be well sorted: the clasts are rounded and constituted primarily by quartz and feldspar whereas micas are very rare. Fossils are absent.

The wide valley, where the windgap between the Cecita and the Lese rivers is located (fig. 1), appears to be filled by several alluvial fan systems presently inactive and partially dissected. Unfortunately the related deposits, Quaternary in age (Marchetti & *alii*, 1970a) are not exposed, although well-rounded pebbles are widespread in ploughed fields.

We have extracted nine stream long profiles (see fig. 3 for location; fig. 8): all of them show peculiar shapes. Sabatino River long profile is in general concave up, but it appears to be composed by three segments: the one above ca. 500 m is straight, the central one is convex, and the one below ca. 200 m is slightly concave and corresponds to a change from narrow to wide valley. The edges of the central knickzone correspond to E-W tectonic lineaments as indicated by the arrows in fig. 8.

Malfrancato River has a concave up profile, characterised in its upper portion by two wide knickzones, one in

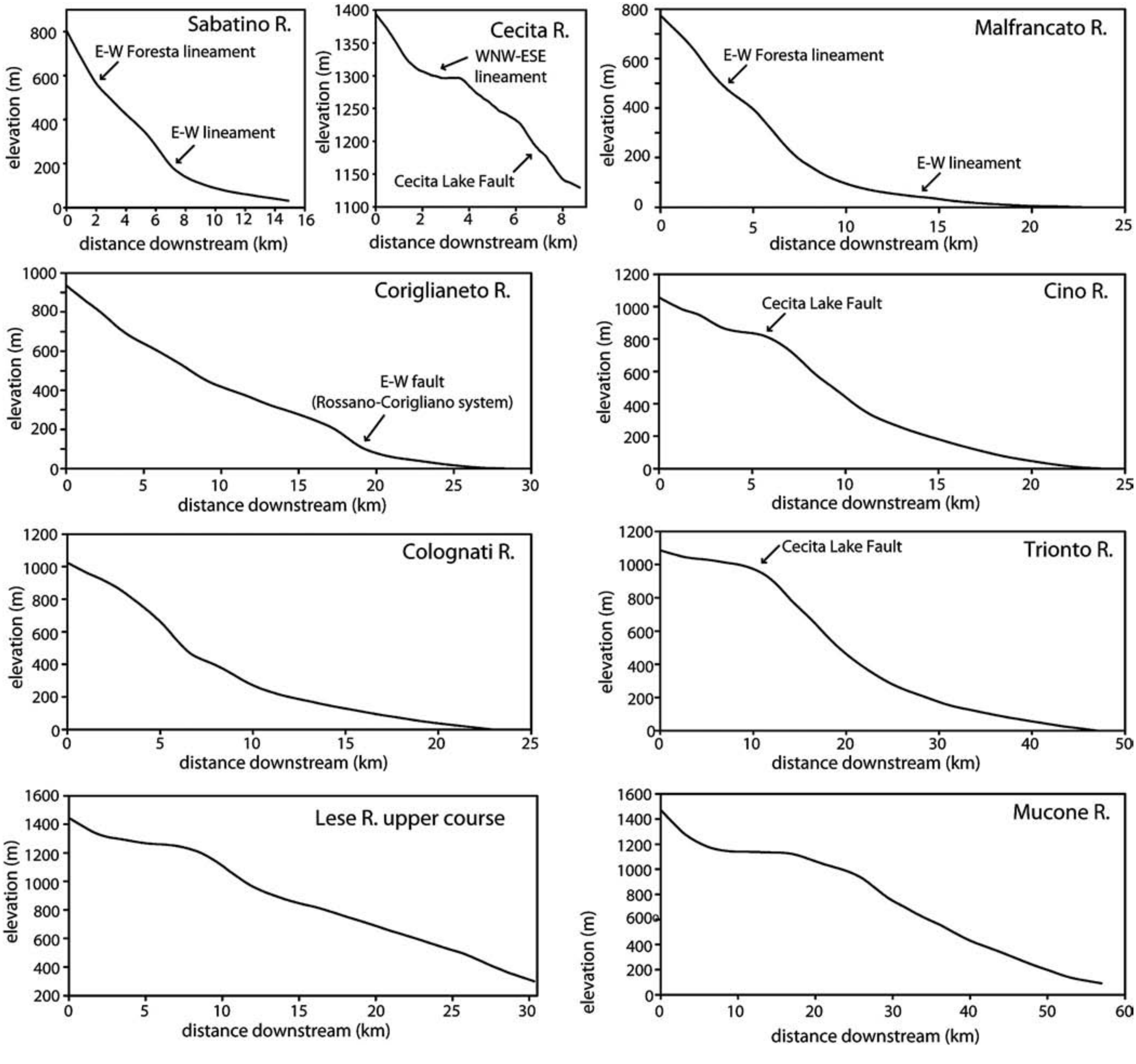


FIG. 8 - Longitudinal profiles of the study streams (see location in fig. 3), showing peculiar shape. The arrows indicate where the fluvial valleys are crossed by tectonic lineaments. Note that, comparing with the long profiles in Molin & *alii* (2004), a different method of extraction provide diagrams of different detail, but of similar shape.

between 220 and 500 m of elevation and one above 500 m. The latter channel gradient change corresponds to the E-W Foresta Line (fig. 8). The lowermost segment of the Malfrancato River profile is concave with a light knickpoint at around 30 m and corresponds to a change from narrow to wide valley.

The Coriglianeto River long profile has a concave up shape with a knickpoint at an elevation between 100 and 200 m, which coincides with a WNW-ESE extensional segment of the Rossano-Corigliano System (fig. 8). Just upstream of this knickpoint, three mostly straight segments (which boundaries are at 450 and 700 m) could be identified.

The Cino River long profile, that is in general concave up, could be divided into three concave segments separated by two convex knickzones (fig. 8). The channel gradient change located at 800 m correspond to the northern extension of the NNW-SSE Cecita Lake Fault. Upstream of it, the valley widens containing the two orders of terraces close to Baraccone village (see description above). The segment above ca. 950 m correspond to a wide valley where a windgap between Colognati and Cino rivers is located.

The Colognati River long profile is characterised by two main knickzones: the lower one is at an elevation between 200-450 m, whereas the upper and larger convex segment extends from 450 to 950 m (fig. 8). Both of them correspond to a narrowing valley, whereas below around 200 m, the channel becomes braided.

The Trionto River has a long profile divided into two parts by a wide knickzone (fig. 8). The segment downstream the knickzone is regularly concave up, the one upstream (above around 950 m of elevation) is mostly flat flowing through the Sila plateau. Just upstream the change in channel gradient, that corresponds to the Cecita Lake Fault, the Difesella deposits crop out, whereas along the headward course of Trionto River the fluvial deposits of I Cotri and Campo Rotondo are located (figs. 1 and 3).

The Cecita River, a small influent of the Cecita reservoir, has a peculiar long profile (fig. 8). The uppermost portion is slightly convex, but it becomes concave down to an elevation of ca. 1300 m. Here the stream incised the fan deposits filling the wide valley that more to the east becomes a windgap between Cecita and Lese drainages (figs. 1 and 3). This wide valley is cut by a lineament oriented WNW-ESE (fig. 8). At elevations lower than 1300 m, where the valley narrows and deepens, the stream long profile is mostly convex including several knickzones. In between two of them, the Cecita Lake Fault intersects the stream (fig. 8).

The long profile of the upper course of Lese River is almost straight (fig. 8). Above around 1200 m becomes flat and corresponds to a portion of the wide valley where the Cecita/Lese rivers windgap is located.

The Mucone River long profile consists, from mouth to head, of a almost straight channel, a knickzone coincident with the stream entrance in the Sila plateau, and an upper concave up channel upstream of the dam of Cecita Lake (fig. 8). This uppermost portion could be interpreted as related to the dam that prevents the river to incise the plateau. In fact, it is interesting to note that before the dam construction in the '50s, a flat morphology (called Piano di Cecita; Amanti & *alii*, 2002) was in the same location of the present reservoir. This indicates that, although presently the dam prevent the Mucone to erode headward, it did not incise this portion of the Sila plateau neither before the dam construction.

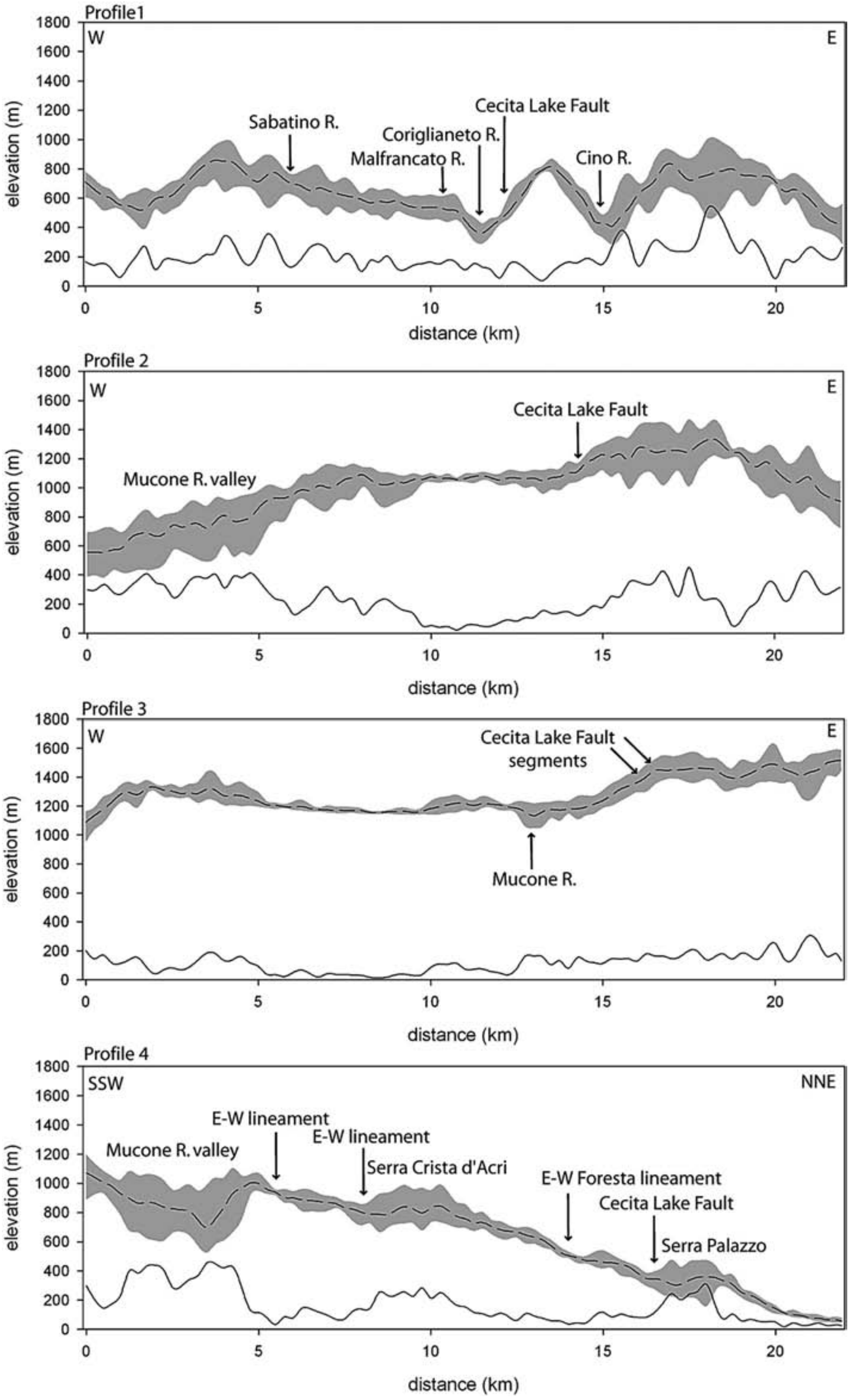
We have extracted four swath profiles (see fig. 3 for location) that describe the maximum, minimum and mean elevation patterns in the study area. We also calculated the local relief for each sections to show the variation of fluvial incision. The northernmost E-W profile (denominated Profile 1; fig. 9) indicates a decreasing topography from W to E, interrupted abruptly by the Coriglianeto River valley. Indeed the latter that is the most deep fluvial incision and corresponds to the northernmost continuation of the Cecita Lake Fault, is the boundary between two areas at different mean elevation: the one to the west is much lower than the eastern area. This is confirmed by the pattern of the residual topography that shows a decrease from west to east towards the Coriglianeto Valley and then an increase that records a higher dissection of the eastern portion of northern flank of Sila.

The central E-W swath profile (Profile 2; fig. 9) describes the very low relief upland located on Sila Massif top. To the west the topography gently decreases towards the Crati River valley, but the relatively high values of local relief are led by the Mucone River deeply incised valley. East of the Sila high-standing plateau, the maximum topography reaches the higher elevation and the local relief increases recording the stronger incision of the plateau edge and of the Sila flank. Note that in the easternmost portion of the Sila plateau, the Quaternary deposits outcropping at Case Bonis are located (figs. 1 and 3): here the Cecita Lake Fault intersect the cross section.

The southernmost E-W swath profile (Profile 3; fig. 9), located immediately north of Cecita Lake, cuts across the plateau, showing the poorly dissected upland surface. A little increase in local relief occurs towards the plateau edges, that rarely exceeds 200 m. The incision of Mucone River downstream of the Cecita Lake dam appears in contrast with the poorly dissected Sila plateau. In fig. 9 the arrows indicate where the swath profile intersects two segments of the Cecita Lake Fault.

The NNE-SSW swath profile (Profile 4, fig. 9) shows a quite regular decreasing slope interrupted by the huge incision of Mucone River and by two peaks: Serra Crista d'Acri and Serra Palazzo (fig. 1). Higher values of local relief correspond to these interruptions, whereas the rest of northern Sila slope appears scarcely dissected. Note that the northern flank of Serra Palazzo corresponds to the northernmost continuation of the Cecita Lake Fault. Upslope, around 500 m of elevation, a U-like form clearly appears. It is the old through-shaped small valley corresponding to the E-W Foresta Line and to the outcropping of the Pliocene-Lower Pleistocene fluvial deposits described above.

FIG. 9 - Swath profiles (Profiles 1, 2, 3, 4) cutting across the study area (for location see fig. 3) and representing the trend of maximum and minimum (in grey), average (dashed line) elevation; a residual (black line) topography, resulting from the subtraction between minimum and maximum elevation, displays the pattern of local relief.



The slope map (fig. 10a) shows the low-relief surface located on the Sila high-standing plateau. The latter is strongly dissected only by the Mucone River that forms a deep incision up to around 1100 m of elevation, less than 1 km downstream the Cecita reservoir dam. The plateau is surrounded by the warm colours that indicate the higher steepness of the valley flanks of the streams that are headward eroding the Sila margins. An exception to this pattern is the area west of Corigliameto River valley: it shows lower slope values with respect to the rest of Sila flanks.

The local relief map (fig. 10b) provides a good tool to visualize the spatial variation in fluvial incision in the

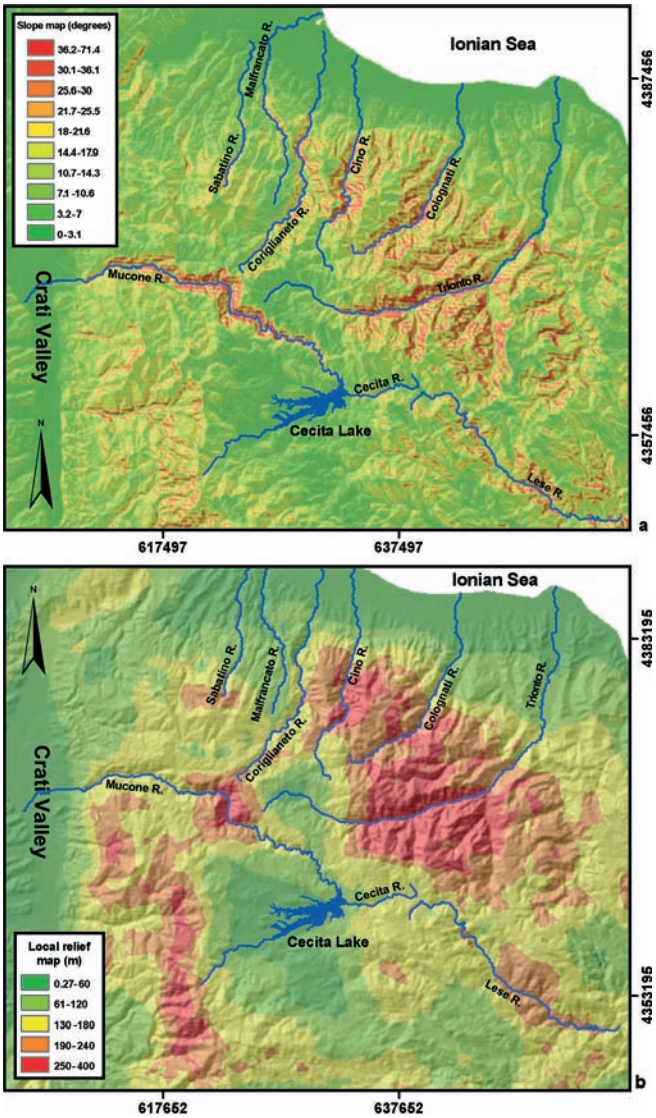


FIG. 10 - a) Slope Map of the study area: the rolling upland of Sila Massif in dominant green/yellow colours is surrounded by the red/orange colours that represent the high steep slopes of the valleys deeply incised in the Sila flanks; b) Local relief map of the study area: it shows the lower values of local relief located in the hangingwall of the *Cecita Lake Fault* and in general on the Sila Massif top, whereas the higher values correspond to the deeply incised Sila flanks.

study area. The topography of northern Sila appears more deeply incised to the east, where the Cino, Colognati and Trionto rivers flow. On the contrary, west of Coriglianeto River there are relatively low values of residual, confirming that this river is locally a sort of boundary between two areas of different landscape evolution. More to the south, in correspondence with the Sila high-standing plateau, the local relief is very little, reaching the lower values in the area including the Cecita Lake. To the south-west, high values of relief correspond to the incision of Crati River tributaries of the western flank of the Sila Massif.

DISCUSSION AND CONCLUSION

We have investigated the drainage pattern of the northernmost portion of the Sila Massif, coupling field survey and topographic analysis. Our results indicated that the evolution of the streams organization in this area is strongly affected by tectonics, and particularly by the Cecita Lake Fault and its northward continuation, never described before. We have outlined it mostly according to morphological and geological evidence. Indeed all along it we could figure out escarpments, straight fluvial valleys, small sedimentary basins, windgaps, and river captures.

In the area of Corigliano village, a huge sedimentary body, interpreted as a fan-fan/delta and Pliocene-Lower Pleistocene in age, could be connected to the Foresta old though-shaped small valley fluvial deposits (fig. 3). It indicates that, before Middle Pleistocene, the Coriglianeto River followed a different path and drained a larger area. The orientation of the Foresta sedimentary body is just a local diversion related to the E-W Foresta Line (fig. 3). This lineament is also pointed out by changes in channel gradient at an elevation of around 500 m in Sabatino and Malfrancato rivers long profiles (fig. 8) and by the Foresta U-shaped small valley in the swath profile named Profile 4 (fig. 9). The course of Coriglianeto River changed as a consequence of the northward continuation of the Cecita Lake Fault that drove, together with the regional uplift, the deep incision of the present Coriglianeto River valley. We do not know when this increase of fluvial erosion started but, in a conservative way, we could suggest it began during the middle Pleistocene, when the regional Quaternary uplift occurred according to many Authors (Vezzani, 1968; Tortorici, 1980, Tortorici, 1981; Ciaranfi & *alii*, 1983; Lanzafame & Tortorici, 1981; Boccaletti & *alii*, 1984; Colella & *alii*, 1987; Moretti, 1993; Tortorici & *alii*, 1995; Moretti & Guerra, 1997; Schiattarella, 1998; Schiattarella & *alii*, 2003; Bigazzi & Carobene, 2004; Schiattarella & *alii*, 2006). So, considering that the Foresta and Corigliano fluvial deposits lie ca. 100 m above the present Coriglianeto thalweg, we could indicatively calculate an incision rate of around 0.13 mm/yr.

The presence of the Cecita Lake Fault and its northward continuation appears to be confirmed by Profile 1 (fig. 9): here the increase of topography from the Corigliancto River to the west indicates the higher subsidence of the hanging wall close to the fault. Similarly it generated the Serra Palazzo peak, lowering the immediately upslope portion of Sila flank (Profile 4 in fig. 9). Anyway, after abandoning the Corigliancto River valley, close to Baraccone village, the Cecita Lake Fault crosses the Cino River valley, forming a small sedimentary basin (fig. 3). Here its activity, coupled with climate changes, allowed the formation of two orders of fluvial terraces. More to the south, the west-side subsidence of the Cecita Lake Fault hanging wall allowed the Cino River to capture the uppermost portion of the Colognati River basin (fig. 3): close to the windgap two orders of terraces are preserved.

Towards the Sila interiors several features show the strong control of the Cecita Lake Fault in landscape evolution. The local relief and slope maps (fig. 10a, b), as well as Profile 2 and 3 (fig. 9), indicate a poorly incised landscape in the hanging wall. Here the fluvial deposits along the Trionto River upper course, the little basin of Pantano, the deposits of the paleo-Cecita Lake, the abrupt change in orientation of the Mucone River main trunk and the windgap between Cecita and Lese rivers (fig. 3) indicate the activity of the Cecita Lake Fault. Moreover, since the Trionto terraces have been dated Upper Pleistocene in age (Calderoni & *alii*, 1989), we could hypothesize a similar age for at least one of the order of fluvial terraces located in Cino River drainage (e.i. Baraccone and Case Bonis deposits). This suggests that the northward continuation of the Cecita Lake Fault may be an active fault.

In a general view, in the Sila interior, the Cecita Lake Fault partially prevented the streams draining the northeastern flank of Sila to incise the plateau and stopped some of them to drain it (like Lese River). In this way, it allowed locally fluvial aggradation, and the paleo-Cecita Lake and ponds formation. Indeed, the hangingwall subsidence strengthened the Cecita River in capturing the Lese River head and induced the Mucone River and its tributaries draining the Sila plateau to flow towards the NE. Here, the direction of Mucone River trunk changes abruptly from SW-NE to WNW-ESE.

In conclusion, our results indicate that the drainage evolution of the study area has been strongly controlled primarily by local tectonics and secondarily by regional Quaternary uplift. In particular, we suggest a northward continuation of the NNW-SSE extensional structure named Cecita Lake Fault (Guerra & *alii*, 2000; Moretti, 2000; Galli & Bosi, 2004). Indeed, probably since the late Pleistocene, this tectonic system re-organized the northern Sila drainage by the west-side down subsidence of the hanging wall.

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