Il Quaternario
Italian Journal of Quaternary Sciences
***18**(1), 2005 - Volume Speciale, 203-211*

GEOMORPHOSITES IN THE LANDSCAPE OF MONTI DEL FURLO (NORTHERN MARCHE APENNINES)

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ABSTRACT: A. Diligenti *et al.*, *Geomorphosites in the landscape of* Monti del Furlo *(northern Marche Apennines)*. (IT ISSN 0394-3356, 2005).
Three geomorphosites pertaining to the Monti del Furlo are taken into consideration. Such area embraces the northernmost sector of an extended anticline ridge and is almost entirely included into a recently created Natural National Reserve. It is therefore clear how important it is in a naturalistic perspective. Moreover, the cultural importance of this site is stressed by the Roman Via Flaminia archaeological remains. This area also benefits from a great geologic/palaeontologic relevance, besides being really notable from a geomorphologic standpoint. In actual fact, the mountain ridge in hand is transversally cut by the Furlo Gorge, one of the most valuable and attractive geomorphosites in the Marche Apennines. Furthermore, this important site can be associated with two other areas which, although not so remarkable as the Furlo Gorge, are worth improving as geomorphosites on account of their peculiar scientific, educational and scenic value.

RIASSUNTO: A. Diligenti et al.*,* Geomorfositi nel paesaggio dei *Monti del Furlo* (Appennino Marchigiano settentrionale). *(IT ISSN 0394-3356, 2005).*
Il rilievo anticlinale dei Monti del Furlo è conosciuto principalmente per la famosa omonima gola incisa profondamente dal fiume Candigliano attraverso i terreni giurassici-paleogenici della Successione Umbro-marchigiana. Il territorio dei Monti del Furlo possiede un patrimonio geologico (peculiarità strutturali e stratigrafiche e famose località fossilifere), biologico (particolari specie floristiche e faunistiche) e geomorfologico (la gola e i paesaggi circostanti) che si integrano felicemente con paesaggi spettacolari, oltre a inserirsi in un contesto di notevole significato storico-archeologico (per esempio la Via Flaminia Romana che attraversa la gola). I Monti del Furlo, anche per questi motivi, sono stati elevati al rango di Riserva Naturale Statale al cui interno sono inseriti anche molti sentieri ed itinerari consigliati per l'osservazione delle caratteristiche naturali più rilevanti.
La gola del Furlo rappresenta un magnifico esempio di gola diaclinalica, forma molto caratteristica e abbastanza comune nei paesaggi appenninici marchigiani. Per questo è stata scelta nell'ambito del Progetto Ministeriale "Geositi nel paesaggio italiano" come geomorfosito da studiare, conservare e valorizzare. Il presente lavoro vuole evidenziare il ruolo fondamentale che tale sito possiede nella comprensione dell'evoluzione del paesaggio marchigiano, in particolare per la genesi delle gole trasversali alle strutture tettoniche. Al suo interno sono localizzati e descritti elementi geomorfologici caratterizzanti e peculiari che sono componenti chiave nella interpretazione del paesaggio e contribuiscono inoltre alla bellezza scenica del geomorfosito.
Nelle vicinanze della gola, sempre all'interno della Riserva Naturale, sono stati individuati altri due geomorfositi, la valle de "Il Buzzo" e la frana di Ca i Fabbri, che, oltre a costituire individualmente aree di rilevante interesse geomorfologico, contribuiscono contestualmente alla conoscenza dell'intero paesaggio dei Monti del Furlo.

Keywords: Geomorphosites, Furlo Gorge, Marche Apennines.

Parole Chiave: Geomorfositi, Gola del Furlo, Appennino Marchigiano.

1. FOREWORD

The anticline mountains of Pietralata-Paganuccio Mts. (respectively 888 and 976 m high, here called "*Monti del Furlo*", according to a local designation) are well-known primarily for housing the famous Furlo Gorge, a striking canyon deeply cut by the Candigliano River (Metauro River basin) across the Jurassic-Paleogene calcareous and marly-calcareous formations of the autochthon Umbria-Marche Succession. The Furlo Gorge cross-cuts an anticline mountain ridge (Figs. 1, 2): with the Frasassi one (famous for its amazing caves above all), it is the best example of such puzzling landforms so characteristic of central Italy. Besides, it is one of the best geomorphosites (*sensu* Panizza, 2001, *i.e*. "a site of special geomorphologic interest") in the Marche Apennines. Although impressive as well as crucial to the unravelling of Plio-Quaternary evolution of this sector of the Apennines, the gorge is not the sole geomorphologic peculiarity of the *Monti del Furlo* area. Indeed, other valuable areas (worth improving as geomorphosites) do occur in its vicinity (*cf*. Fig. 2), giving the Gorge itself a surplus value. Hence, in short, the area under discussion can be considered as encompassing more than one geomorphosite of greater or lesser geomorphologic relevance, each contributing to the geomorphologic evaluation of the whole. In turn, each geomorphosite comprises several individual, characterising landforms and/or landform associations of either scientific-educational importance or scenic relevance. More to the point, the *Monti del Furlo* area holds a major geologic-palaeontologic (*e.g.* structural and stratigraphic peculiarities and famous fossiliferous sites), naturalistic (*e.g*.

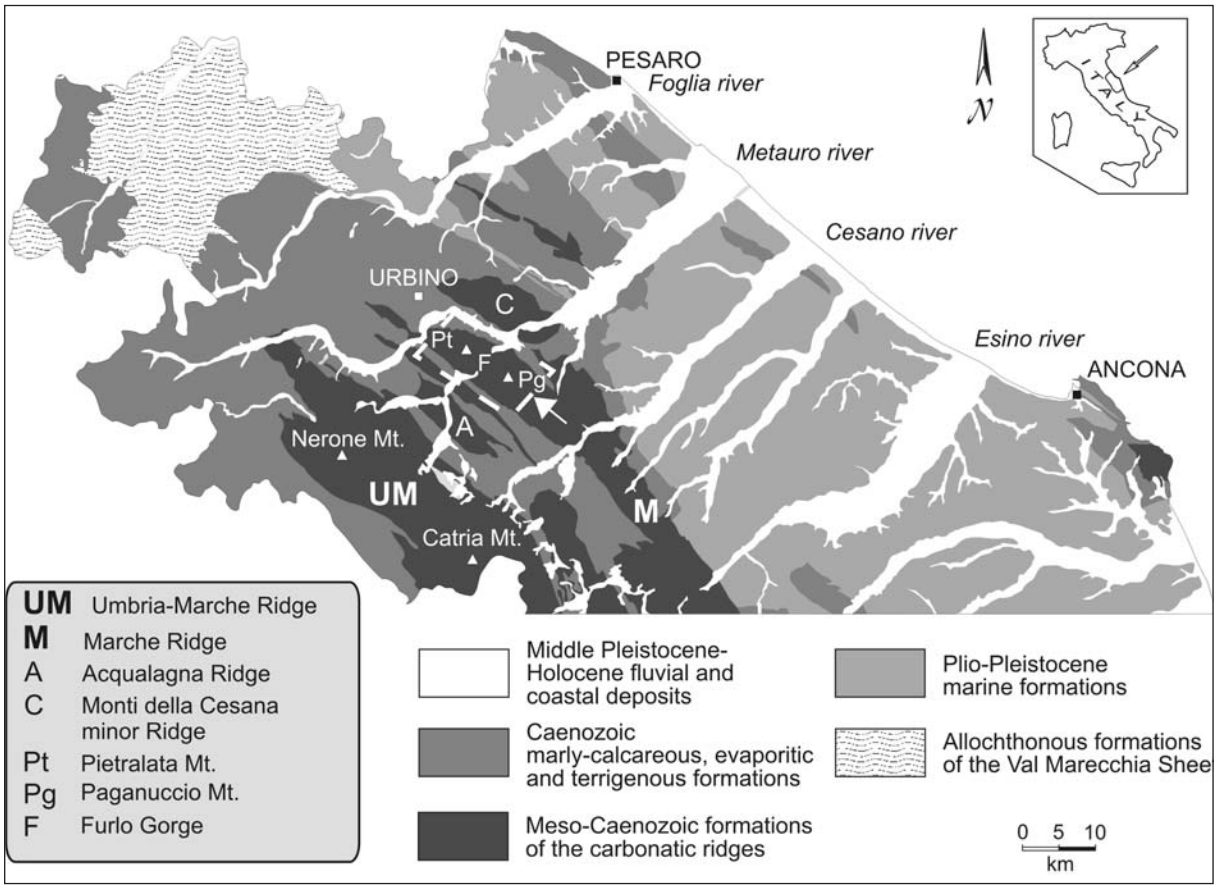

Fig. 1 - Geologic sketch of the northern Marche region and location of the areas discussed in the text.

Schema geologico dell'area nord-marchigiana e ubicazione delle aree trattate nel testo.

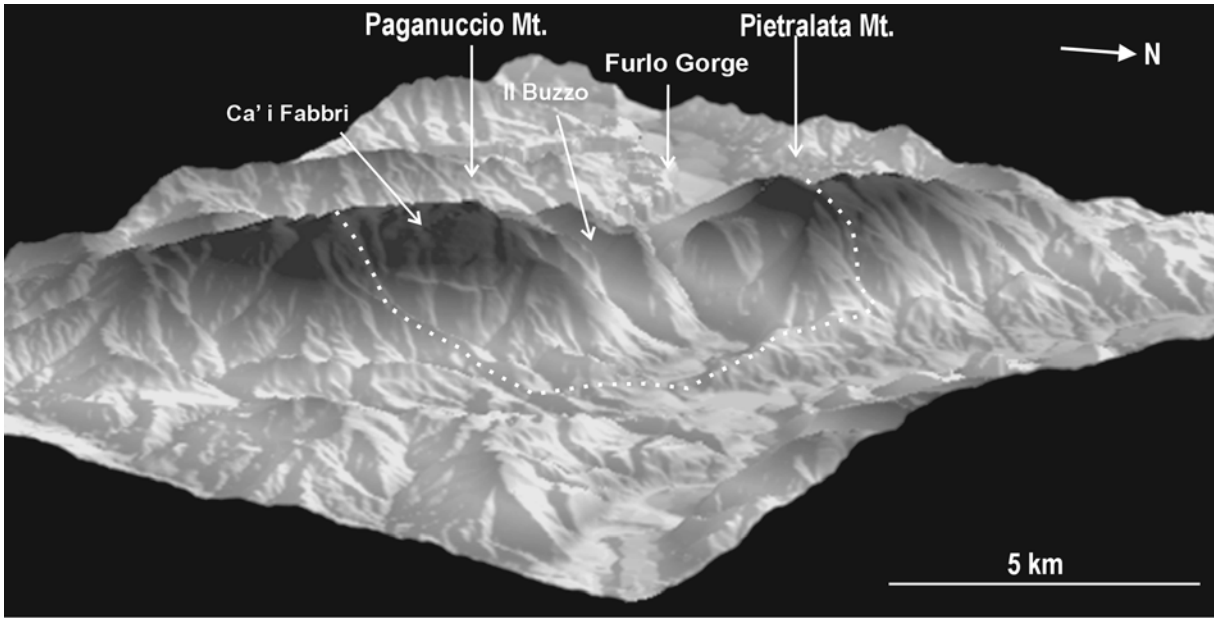

Fig. 2 - Shaded relief of the *Monti del Furlo* anticline ridge with the location of the geomorphosites described in the text. The dotted line indicates the boundary of the study area.

Modello digitale della dorsale anticlinalica dei Monti del Furlo *con l'ubicazione dei geomorfositi descritti nel testo. La linea puntinata indica il limite dell'area considerata nella presente nota.*

occurrence of floristic and faunal peculiarities), landscape (*e.g*. the gorge itself and the surrounding scenery) and historical-archaeological (*e.g.* the Roman *Via Flaminia* remnants) relevance as well. These very essentials of both the Furlo Gorge and its environs have recently made this area become a National Natural Reserve (*Riserva Naturale Statale della Gola del Furlo*), thereby arousing a great and renewed interest of both national and international communities. Hence the *Monti del Furlo* area as a whole can be regarded as a "*landscape unit*" (cf. Panizza & Piacente, 2003, p. 264), where the geomorphologic constituents integrate into a wider naturalistic and historical-cultural geographic context. Therefore, in the framework of the MIUR co-financed project "*The geosites of the Italian landscape: research, evaluation and enhancement*" the Urbino Research Group, taking its cue from such basics and allowing for the global geosites inventory outlines (Wimbledon, 1999), has accounted the *Monti del Furlo* as an area of primary geomorphologic relevance, proposing three individual geomorphosites and adopting this sector of the Marche Apennines as a sample-area for a targeted geomorphologic mapping.

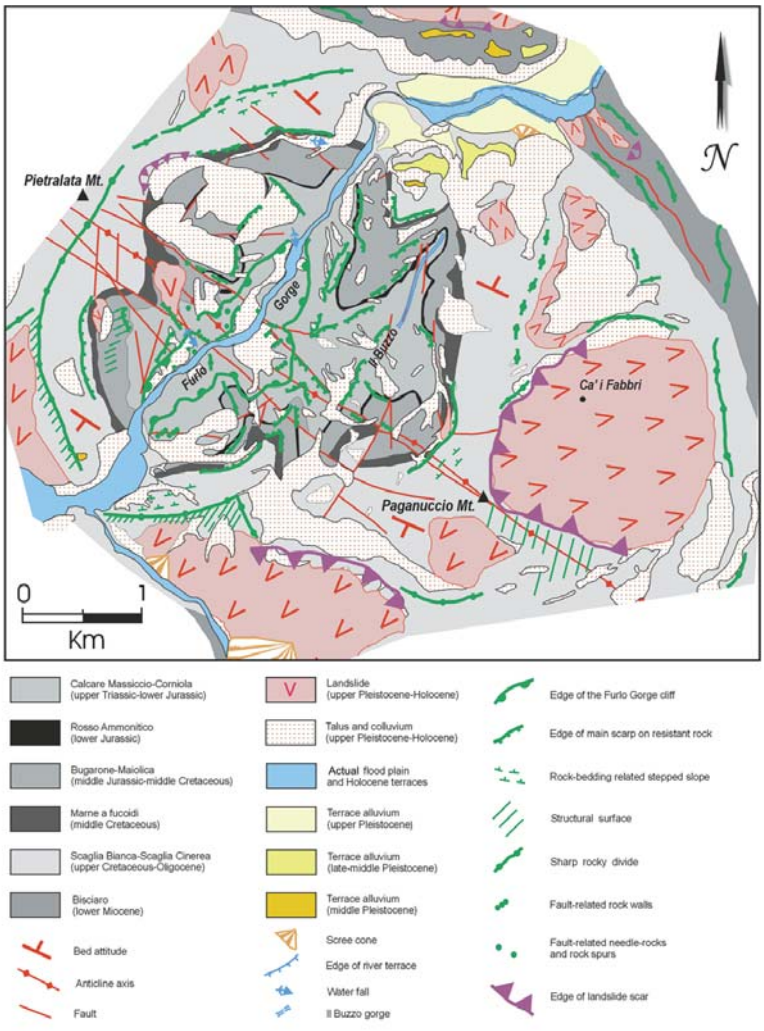

Fig. 3 - Geomorphologic sketch of the *Monti del Furlo* sector enclosing the Furlo Gorge and location of the areas described in the text.

Schema geomorfologico del settore dei Monti del Furlo *comprendente la Gola del Furlo e ubicazioni delle aree descritte nel testo.*

2. GEOLOGIC FRAMEWORK

The Marche regional territory is characterised by a hilly coastal zone, where slightly deformed Plio-Quaternary terrains predominate, merging to the southeast into a mountain chain area mostly corresponding to Meso-Cenozoic folded and thrusted formations of the autochthon Umbria-Marche Apennines domain. It is characterised by two main ridges striking in a c.ca NW-SE direction, the *Umbria-Marche Ridge* (to the SW) and the *Marche Ridge Auct.* (Fig. 1), divided from each other by a broad topographic depression (*cf*. Bisci & Dramis, 1991 and references therein); several minor ridges either join the major ones flanks or stand on the inter-ridge depression (*cf*. Fig. 1). Both the major and the minor ridges consist of Mesozoic-Paleogene mainly carbonate and marly-calcareous units of the *Umbria-Marche Succession* and correspond to asymmetric, mostly thrusted, NE-vergent anticlinoria (*cf*. Deiana & Pialli, 1994 and references therein).

The *Monti del Furlo* area overlaps the north-western termination of the *Marche Ridge* and consists of both the Paganuccio and Pietralata anticline mountains, divided by the *Furlo* Gorge (Figs. 1, 2, 3). The Paganuccio Mt.-Pietralata Mt. *(i.e. Monti del Furlo*) anticline, characterized by an average N120 axial trend, is a slightly asymmetric box fold lacking in any clear evidence of major emergent thrusts on the forelimb. As a rule, the anticline, plunging both to the NW (anticline periclinal closure) and to the SE (an axial depression), shows a marked local axial culmination in close proximity to the Furlo Gorge.

The area at issue consists (*cf.* Cecca *et al.*, 1999) of carbonates, cherty carbonates, marls and calcareous marls of the Umbria Marche Succession (Figs. 3, 4), unconformably covered by a discontinuous and relatively thin mantle of quaternary alluvium and slope deposits. The lower-Jurassic *Calcare Massiccio* formation, an over 500 m thick unit in which the Furlo Gorge is entrenched (*cf.* Figs. 3, 4), consists of massive dolomitic limestones of carbonate platform environment and is the oldest outcropping unit. It is overlain by a *c.ca* 600-700 m thick sedimentary "multilayer" extending from the lower Jurassic up to the lower Miocene, consisting of calcareous/marly-calcareous units alternating with marly/marly-calcaraeous ones. The Jurassic units, ranging from the *Calcare Massiccio* up to the base of the *Maiolica* formation, show rather complex facies associations and significant lateral litho-stratigrafic differentiation (*cf*. Cecca *et al*., 1999 and references therein), hinting at local depositional environments matching up with a fault-block seamount slope. On the contrary, the Cretaceous-Miocene units (from the mid-upper part of the *Maiolica* up to the *Scaglia Cinerea* and *Bisciaro* formations), display a significant lateral continuity and rather homogeneous lithofacies representative of an overall pelagic depositional environment. Local occurrence of slumps and calciturbidites is

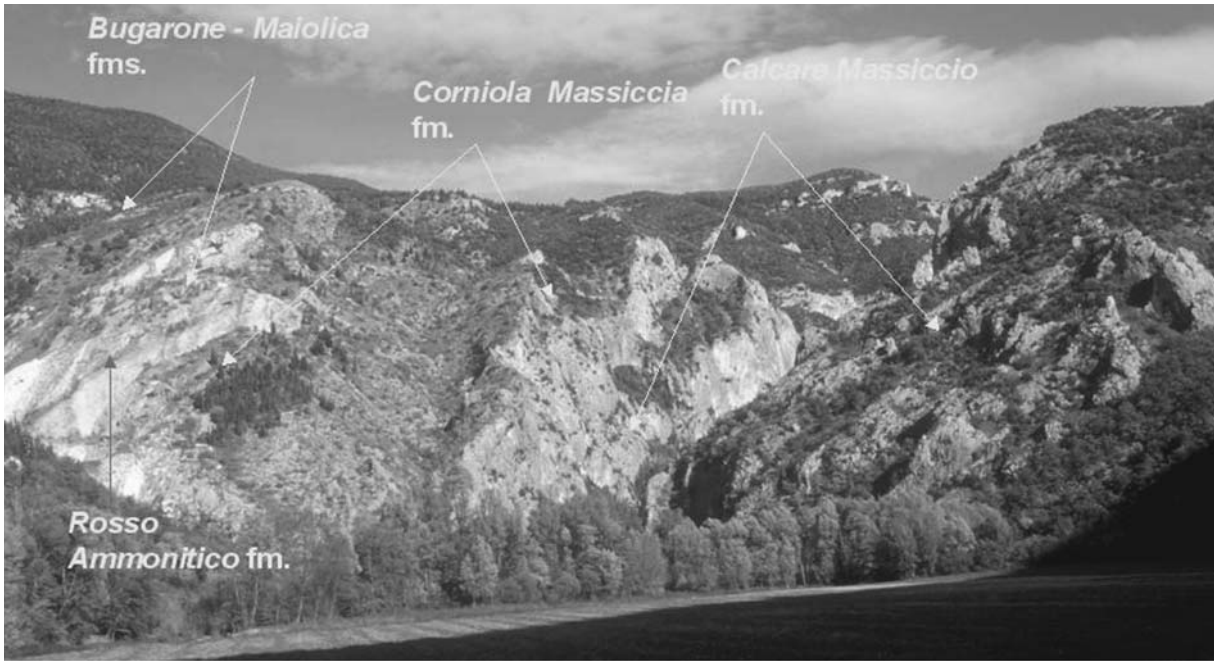

Fig. 4 - Panoramic view of the south-western side of the *Monti del Furlo* anticline ridge showing the outcropping Jurassic formations. Please note the entrance of the Furlo Gorge and, on the foreground, the flat top-surface of the Holocene terrace alluvium.

Veduta panoramica del fianco sud-occidentale della dorsale anticlinalica dei Monti del Furlo *con indicate le formazioni giurassiche affioranti. Si notino l'ingresso della Gola del Furlo e, in primo piano, la superficie pianeggiante delle alluvioni terrazzate oloceniche.*

also noticeable (*cf.* Alvarez & Lowrie, 1984; Stow *et al.*, 1986) as a clue to topographic irregularities in the palaeo-basin floor.

Because of its geographical collocation as well as of the occurrence of both many good outcrops and significant facies differentiation in quite a small zone, the *Monti del Furlo* area is to be regarded as an important geologic site. Many of its outcrops allow for detailed visualization and reconstruction of crucial stages of the Marche Apennines meso-cenozoic geologic history, from the drowning of the lower-Jurassic shallow-water carbonate platform to the establishment of persisting pelagic conditions (*cf.* Various Authors, 1991; Cecca *et al*., 1999). Moreover, several fossiliferous sites as well as regional-markers outcrops (*e.g*. the *Bonarelli* level or the K/T level) arouse both the scientific community and keen naturalists' interest in the geologic heritage of this area.

3. THE GEOMORPHOSITES

The *Monti del Furlo* area, corresponding to the northernmost sector of the *Marche Ridge* (Fig. 1) anticline relief, displays such a clear morphostructural imprint (Figs. 2, 5) that it can be included (togheter with Petrano Mt., see Nesci *et al.*, 2005) among the best examples of carbonatic anticline ridges in the Central Apennines. In addition, the geomorphologic interest of the area is greatly increased by an impressive transverse canyon, namely the Furlo Gorge.

The main sectors of the ridge (*i.e*. Monte Pietralata and Monte Paganuccio, Fig. 2) perfectly display both the rounded geometry of the anticline and its north-west and south-east plunge-out areas. On the anticline flanks well developed homoclinal ridges and flatirons are found (Figs. 2, 6). The morphostructure has developed its peculiar arrangement by different geomorphic processes, from weathering and mass movements to slope-wash and cryonivation. Whatever the occurring process, selective weathering and erosion have often been able to highlight both lithologic contrasts of the Jurassic-Miocene "multilayer" and structural features, such as fault-zones and bended bedding surfaces. Since weathering and erosion have been more effective under Pleistocene cold climatic conditions, several structural landforms characterising the modern landscape of the area must be regarded as almost entirely derived from past morphogenetic stages. Some peculiar landforms (*i.e*. broad natural amphitheatres and Ricter slopes), in particular, are relics of past cold climatic conditions. Others, such as those related to mass-wasting or weathering, are still more or less active, even though they can have experimented stages of more intense activity in the past.

The whole area is crossed by several paths and roads, some of which can be of peculiar geomorphologic interest, since they cross both the Furlo Gorge and the nearby geomorphosites. As a matter of fact, they allow people to approach many significant landforms and to have panoramic views on both the Monti del Furlo area and on the Metauro-Candigliano valley and terraces. Two of them match with as many geologic itineraries described by Coccioni *et al.* (1994) and Savelli & Tramontana (2001): since they also cross areas of major geomorphologic interest, they are suitable for educational as well as scientific purposes and worth improving as geomorphologic paths too.

3.1 The Furlo Gorge Geomorphosite

The principal geomorphologic peculiarity of the area is, without any doubt, the Furlo Gorge, a deep canyon cross-cutting the anticline ridge (Figs. 2-5 and 7-8). As a matter of fact, indications which are important for both scientific and educational standpoint definitely arise from such an attractive and scenic gorge (*cf.* Bartolini & Peccerillo, 2002). Its sub-vertical walls (Fig. 8), hanging over 500 m high on the present river, have been cut into the dolomitic limestones of the *Calcare Massiccio* formation by the Candigliano River, the major right tributary of the Metauro River. The evolution of the drainage net of the Metauro-Candigliano River basin started, perhaps, as long ago as in lower Messinian time, but only during the upper Pliocene-Quaternary did the net achieve the essentials of its modern organization (*cf.* Mayer *et al.*, 2003). It was just at that time that the anticline ridge bypass was performed according to still largely uncertain mechanisms, which are object of a long-lasting debate and of different interpretations (*e.g.* Mazzanti & Trevisan, 1978, Alvarez, 1999 and references therein). The Furlo Gorge deve-

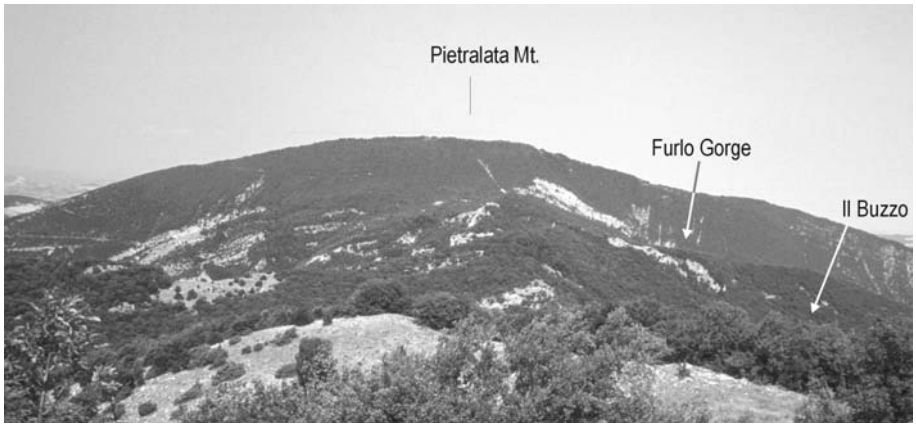

Fig. 5 - Panoramic view emphasizing the morphostructural arrangement of the *Monti del Furlo* anticline ridge.

Veduta panoramica che evidenzia l'assetto morfostrutturale della dorsale anticlinalica dei Monti del Furlo.

Fig. 6 - Flatirons on the resistant limestones of the lower Miocene *Bisciaro* formation. North-eastern flank of Pietralata Mt., *Monti del Furlo* anticline ridge.

Flatirons modellati sui calcari della formazione del Bisciaro *(Miocene inf.). Fianco nord-orientale di M. Pietralata, dorsale anticlinalica dei* Monti del Furlo.

Fig. 7 - The upstream sector of the Furlo Gorge.

Veduta del tratto iniziale della gola del Furlo.

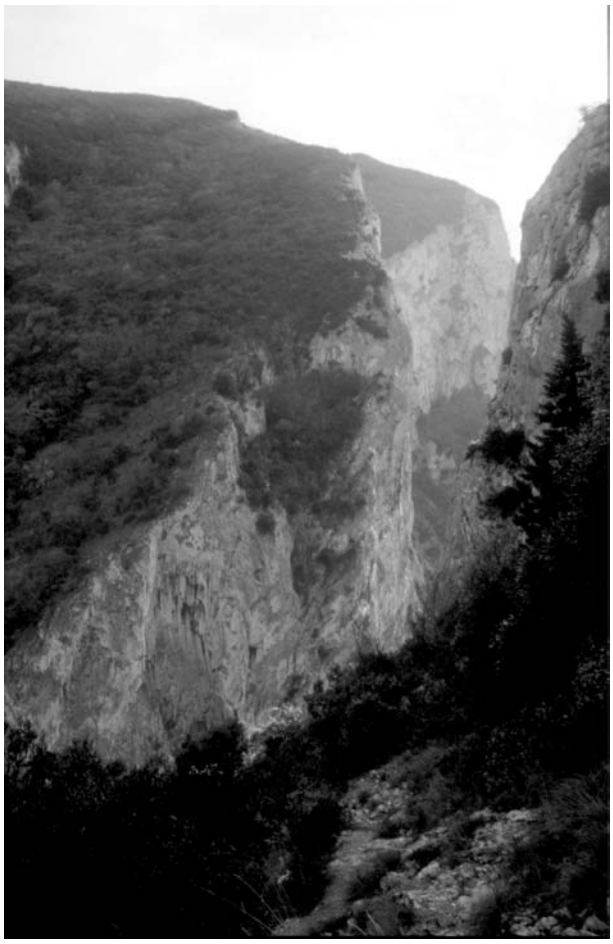

Fig. 8 - Vertical cliffs in the downstream reach of the Furlo Gorge.

Le pareti verticali del tratto iniziale della Gola del Furlo.

lops along a dominant SW-NE joint direction (Mayer *et al.*, 2003) just corresponding with a pronounced axial culmination of the anticline, as shown both by geologic data and the morphostructural arrangement itself (*cf.* Fig. 2). Moreover, a second narrow canyon (*i.e.* the so-called "*Il Buzzo*") parallel to the main one cuts the external flank of the anticline ridge less than 1 km to the south-east of the Furlo Gorge (Figs. 2, 3, 5). The unusual structural position as well as the occurrence of a second minor canyon, have recently led Mayer *et al.* (2003) to interpret the Furlo Gorge as the result of capture mechanisms, rather than superposition followed by antecedence as previous Authors asserted.

In the geomorphosite area, the youngest (*i.e.* second half of the middle Pleistocene-Holocene) evolution stages of the valley reach enclosing the gorge, are underlined by fluvial terraces occurring on both flanks of the anticline ridge just outside the gorge (*cf.* Fig. 3, 4, 9). In fact, several well preserved terraces and some terrace-alluvium outcrops occur close to it, reaching elevations as high as 155 m above the modern stream (Nesci *et al.*, 1990, p. 69), and highlighting the presence of four main cycles of aggradation related to as many Pleistocene cold stages (*cf.* Nesci *et al.*, 1995 and references therein). In actual fact, both the presence of terraces and their altitudinal distribution underline a vertical uplift of the structure, but no evidence of terrace deformation relating to active thrusting and folding of the anticline can be alleged (*cf.* Di Bucci *et al.*, 2003).

Besides these major subjects of scientific, educational and scenic value, both in the Furlo Gorge and in its vicinity the geomorphosite includes many other minor -yet noticeable- landforms and landform assemblages, which contribute to enhance the geomorphologic significance of the site. Some of them are worth mentioning, as follows.

Small hanging valleys ending against the edge of the Furlo Gorge cliffs, although dried up for most part of the year, are able to produce impressive waterfalls when heavy storms and/or rapid snow-melt occur (Fig. 10). Narrow potholes can also be observed at the foot of the ephemeral waterfalls. Such suggestive landforms due their origin to a huge difference in down-cutting rates of the Candigliano River and of its small ephemeral tributaries flowing on the hard dolomitic limestones at the core of the anticline ridge. Small caves (e.g. *Grotta del Grano, i.e.* "corn cave", cf. Fig. 11), tens of meters large but only a few metres deep, owing their origin to moderate karst processes associated with cryo- and thermo-clastic processes, characterise the feet of the cliffs. In addition, the *Calcare Massiccio* walls of the Furlo Gorge bear well-developed weathering landforms both on relatively weak rock-beds and along faults. In detail, a series of weathering niches developed both along strata and along joint systems (Fig. 11). In the first case, apart from a very crude bedding of the dolomitic limestones forming the gorge walls, the occurrence of weaker beds is locally underlined by a series of weathering niches arranged along curved lines which follow the bending of the anticline structure cross-cut by the gorge. In the latter case, because of poor re-cementation by carbonates, the rock has been made less resistant to weathering all

Fig. 9 - Upper Pleistocene (uP) and late-middle Pleistocene (mP) fluvial terraces close to the downstream termination of the Furlo Gorge.

Terrazzi del Pleistocene superiore (uP) e del Pleistocene medio-finale (mP) in prossimità dello sbocco della Gola del Furlo.

Fig. 10 - Waterfalls during a stage of activity of hanging valleys inside the Furlo Gorge.

Cascata in un periodo di attività di una delle valli sospese presenti all'interno della Gola del Furlo.

along the fractured zones, thus improving the production of niches by cryo- and thermo-clastic processes associated with more or less pronounced carbonate solution. On the contrary, narrow rocky walls and ridges as well as sets of rock-spurs (Figs. 12, 13) align with those major faults along which resistant fault-rocks formed because of strong calcium-carbonate cementation. Outside the gorge area such fault-related landforms are lacking because of softer terrains occurrence. They are generally replaced by slopes of fault-line scarps or by fault scarps exhumed by selective erosion (*cf.* Fig. 7.2 in Savelli & Tramontana, 2001).

Fig. 11 - Small caves and weathering niches aligned along both bedding and fracture-systems close to the Grotta del Grano, intermediate sector of the Furlo Gorge.

Nicchie di degradazione lungo sistemi di fratture e superfici di stratificazione in prossimità della Grotta del Grano, settore intermedio della Gola del Furlo.

Fig. 12 - Fault-related rock-spur produced by weathering in the intermediate left side of the Furlo Gorge.

Sperone roccioso prodotto dalla degradazione lungo una zona di faglia, versante di sinistra della Gola del Furlo.

Fig. 13 - Segmented fault-related rock-wall produced by weathering on the intermediate right side of the Furlo Gorge. Please note on the foreground the artificial lake due to damming of the gorge exit.

Muro di faglia parzialmente smantellato dovuto a degradazione selettiva, fianco destro della Gola del Furlo. Si noti in primo piano l'invaso artificiale prodotto dalla costruzione di una diga all'uscita della gola.

Anthropic modifications performed in more or less recent historical time are also noticeable, although flawlessly harmonized with the natural landscape. Specifically, two Roman tunnels (2nd century BC-1st century AD, *cf.* Luni, 1993) chiselled out of rock walls of the Furlo Gorge characterise the canyon entrance. Furthermore, a dam built up at the beginning of the 20th century has produced an attractive, narrow and deep artificial lake inside the gorge itself.

3.2 Geomorphosites in the Furlo Gorge vicinity

Since the Furlo Gorge is not the one and only significant geomorphologic element of the area under discussion, two sites close to the Gorge and valuable as geomorphosites in their own right, are worth mentioning. One of them (*i.e. Il Buzzo*) is related to the Furlo Gorge geomorphosite, thus contributing to highlight its scientific as well as educational significance. The other one (*Ca' i Fabbri)* is to be considered in order to better understand how important mass movements are in shaping the anticline ridge where the Gorge developed.

3.2.1 Il Buzzo

The so called "*Il Buzzo*", whose geomorphologic importance has just been mentioned, is a very narrow gorge running parallel to the Furlo one (Figs. 2, 3, 5). It consists in a close "V" shaped valley whose bottom is over-deepened by a gorge which in some places is less than two metres wide. The valley, whose head is covered by upper Pleistocene stratified slope-waste deposits, is excavated in well-bedded Jurassic limestones, whereas its bottom is incised in the massive limestones

belonging (according to Cecca *et al*., 1999) to the lower-Jurassic *Corniola Massiccia* formation (*cf*. Fig. 4). "*Il Buzzo*" valley cuts the anticline ridge extending upstream far enough beyond the axis of the structure, so that the initial valley reach falls in the internal anticline flank (*cf.* Fig. 2). Therefore, the valley head is furrowed in the south-western side of the anticline ridge, yet it does not bypass the mountain massif like the nearby Furlo Gorge does. The gorge is run by a minor stream, presently dry most of the year. Its vertical and overhanging walls display a strong passive structural control by joint systems trending in a SW-NE direction. A particular rock bridge (Fig. 14) occurs in the intermediate valley reach, where slid rock-blocks only partly reworked by stream obstruct the valley bottom to a degree.

3.2.2 Ca i Fabbri Landslide

The *Monti del Furlo* mountain ridge is a remarkable natural example of an exhumed anticline, where the geologic structure is distinctly replicated by the relief topography (*cf.* Figs. 2, 5). Although the ridge has been shaped by different processes, the role of mass movements, as in the past, is today one of the most effective (*cf*. Fig. 3). Indeed, the flanks of the anticline ridge have been extensively denudated by more or less shallow landsliding, able to highlight both lithologic contrasts and structural features, such as bended bed-surfaces. These processes are generally favoured by the occurrence of weak marly/clayey-marly interbeds/units as well as by a downslope-dipping of layers prevailing on both the anticline ridge sides. Additional control by intense jointing of rock units can often intervene, emphasizing the local tendency to landsliding. The *Ca i Fabbri* landslide is the best example of several large landslides which are well recognisable all over the anticline flanks (Fig. 3); by the way, it is very close to the Furlo and Il Buzzo gorges and allows for some significant panoramic views. The landslide originates on the upland flats corresponding with the anticline crest. It is a rock-slump extending *c.ca* 2 km downslope all over the north-eastern anticline flank. A fresh, marked arcuate cliff rimmed by tension cracks marks off the landslide head. In the upper part of the slid body, a multitude of characteristic rock-pillars alternating with trenches and counterslopes -although covered by a beech forest- is so evident and distinctive to capture the attention of students as well as of common people walking along the wood paths. The slid mass becomes more and more disrupted and chaotic downslope, where its thickness (over 100 m) is appreciable because of deep gully dissection of the landslide body. Moreover, the landforms freshness indicate a very recent mobilization of the upper sector of the landslide, whereas the occurrence of both deep dissection and smoothing of the sliding-related forms hints to an inactivity at the toe.

Fig. 14 - The curious rock-bridge inside the "Il Buzzo" gorge.
Il singolare ponte naturale all'interno della gola de "Il Buzzo".

ACKNOWLEDGEMENTS

This paper was funded by MIUR to O. Nesci (co-financed project *"The geosites of the Italian landscape: research, evaluation and enhancement"*, 2001). Special thanks to Nicole Savelli for revising the English text.

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