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SCIENCE

Geomorphological features of the Rio della Rocca valley (northern Apennines, Italy)

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This paper presents a geomorphological map of the Rio della Rocca valley, a small catchment located in the lower Apennines of the Province of Reggio Emilia (northern Italy). The geomorphological map has been produced at a scale 1:7500 as a base document within multidisciplinary investigations aimed at the rehabilitation of the area, which is characterised by peculiar geological and geomorphological features and a high scenic value, despite clear evidence of human impact. Since the mid 1950s the valley has been affected by quarrying activities which in some places have deeply changed its environmental and, in particular, geomorphological features. As a part of the research, geomorphological survey and mapping were carried out in order to detect the main slope instability and erosional processes and landforms and, at the same time, to recognise sites of geological and geomorphological interest. Proposals for territorial development have been proposed which take into account geotourism and recreational issues.

Keywords: geomorphological map; anthropogenic landforms; environmental rehabilitation; Northern Apennines; Italy

1. Introduction

The aim of this paper is to present and illustrate a detailed geomorphological map (scale 1:7500) of the Rio della Rocca catchment (Province of Reggio Emilia, northern Italy) which was produced as a base document for the environmental rehabilitation of the area. The catchment is characterised by a great variety of abiotic environments and high biodiversity which has been heavily affected by quarrying activities in recent times.

Considering the high scenic and environmental value of the study area, multidisciplinary investigation of the geology, botany and fauna were completed in order to plan the environmental rehabilitation of the whole valley (Soldati et al., 2009). In this framework, specific attention was given to a geomorphological survey and mapping.

2. Study area

The Rio della Rocca valley is located in the foothills of the lower Apennines of the Province of Reggio Emilia (northern Italy) and covers an area of about 8 km^2 (Main Map) with elevation ranging from 120 and 350 m a.s.l. The Rio della Rocca, the main water course of the valley, is a left tributary of the River Secchia and flows in an E-W direction. Its numerous tributaries have short courses and are set on steep slopes (Figure 1). Their discharge is seasonal and strongly influenced by meteorological events.

The climate is typically temperate, with average annual precipitation of about 800 mm, average temperatures in summer of about 22°C and average temperature in winter of about 3°C.

The northern Apennines have an extremely complex geological structure, characterised by a fold-and-thrust geometry due to the convergence and collision of the Adria and European continental plates (Boccaletti, Elter, & Guazzone, 1971; Klingfield, 1979; Vai & Martini, 2001 and references therein). Starting from the middle Eocene, an already-formed oceanic submarine accretionary prism progressively overrode the subducting continental Adria plate under the European plate. Today, the Ligurian Units, which occupy the topmost part of the Appenine

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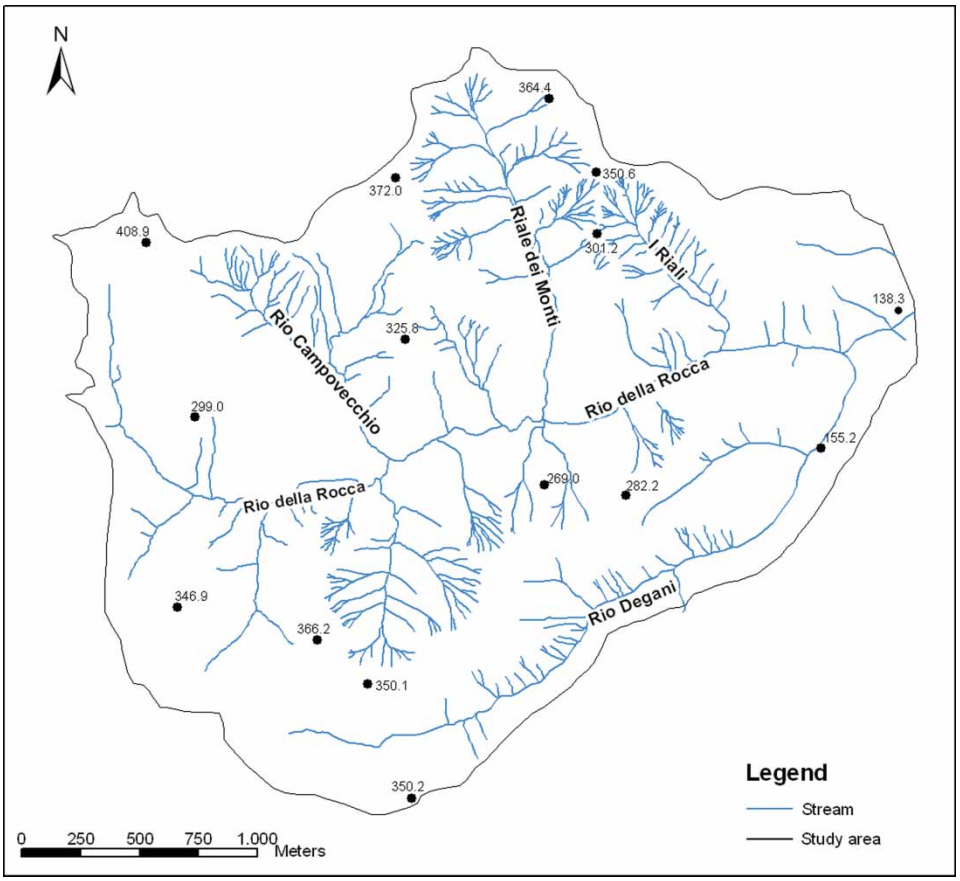

Figure 1. Drainage network of the study area.

tectonic pile, represent this exhumed fossil accretionary prism (Remitti, Bettelli, Panini, Carlini, & Vannucchi, 2012) (Figure 2). From the late Oligocene – early Miocene, the migration of the Appenine deformation front toward the Adriatic foreland has been attributed to the retreat of the subducting continental Adria plate. On the top of the Ligurian accretionary prism, the Epiligurian Succesion is observable, which is made up of marine sedimentary rocks (Remitti et al., 2012, and references therein).

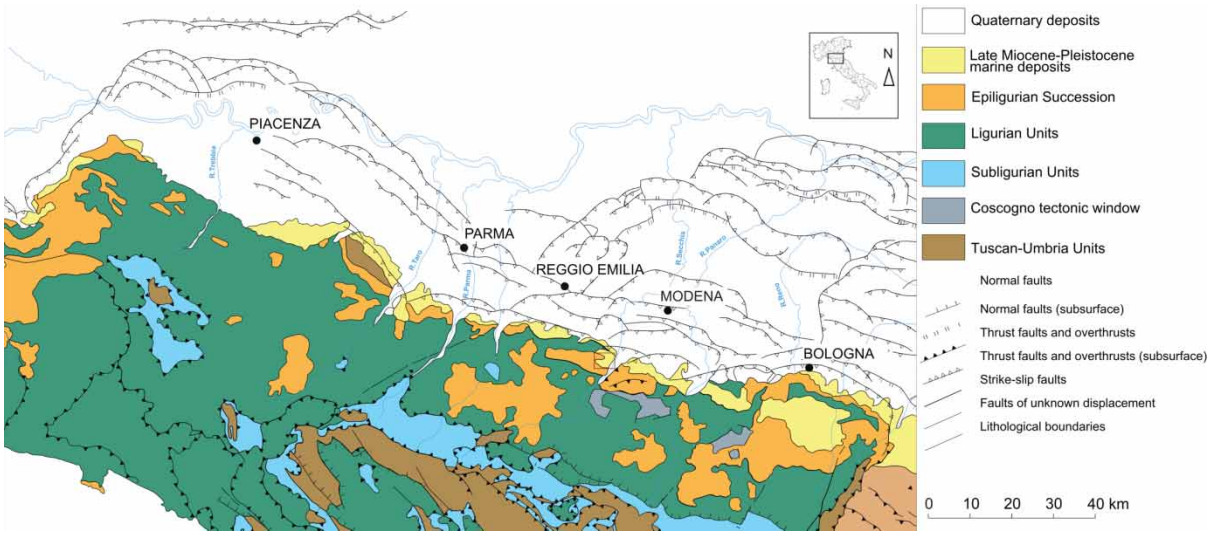

Figure 2. Schematic geological map of the Northern Apennines (modified after Remitti et. al., 2012).

Figure 3. Lithological boundary between Blue Clays (on the top) and Ranzano Formation (at the base) (Photo V.M. Bruschi).

In the study area, sediments ranging from Upper Eocene to Lower Pleistocene mainly outcrop. The main lithological units consist of yellow sandstones belonging to the Epiligurian Succession and grey-blue clays of the marine units of the Apennine margin (Gasperi & Preti, 2005; Gasperi, Bettelli, Panini, & Pizziolo, 2005) (Figure 3). The formations belonging to the Epiligurian Succession outcropping in the area are the Ranzano Formation and the Monte Piano Marls. The *Ranzano Formation* (Upper Eocene – Lower Oligocene) is characterised by a considerable variability of facies, especially with respect to bedding, grain size and sedimentary structures. It consists of turbiditic bodies, including coarse to pelitic sediments. Two members of the this formation outcrop in the study area, the Val Pessola Member made up of lithoarenites, conglomerates and pelites, including an arenaceous-conglomerate lithofacies, and the Varano de Melegari Member consisting of a grey-greenish arenaceous-pelitic alternation. The *Monte Piano Marls* (Upper Eocene – Lower Oligocene) are characterised by red and reddish to greyish and greenish clays, marly clays and marls. The upper part of the succession is made up by Late Miocene – Pleistocene sediments belonging to the Colombacci Formation and the Blue Clays. The *Colombacci Formation* (Messinian) consists of whitish marly clays and clayey marls, deposited in both shallow and deep-water basins developed during the final phase of the Messinian salinity crisis. The *Blue Clays* (Lower Pliocene – Lower Pleistocene) are composed of massive clays and marly clays, grey-blue in colour which witnesses the return to fully marine conditions; a facies of this formation, including sands and arenaceous-pelitic alternations (San Valentino Member), outcrops in the south-western sector of the study area.

From a geomorphological perspective, the valley shows a gentle hilly aspect, characterised by badlands, landslides and quarries. Landform development is deeply influenced by the presence of rocks showing a different mechanical behaviour. Gravitational and erosional processes, as well as human activities, have mainly contributed to the shaping of the valley (Soldati et al., 2009). The latter have played a fundamental role in modelling the physical landscape of the area in recent times. In the Sassuolo area (Province of Modena), very close to the study area, there is the largest tile making district in the world, with an annual output of around 450 million square metres, accounting for approximately one-sixth of global production (Dondi, 1999). The Sassuolo Ceramic District was developed during the 1960s and 1970s, partly thanks to the wide availability of clayey raw materials with suitable

Figure 4. Panoramic view of the inactive translational slide located at the base of the southern slope of Mount Pradella (Photo M. Soldati).

technical properties. The clays used by the ceramic industry come from different formations belonging to both the Ligurian and Epiligurian units, as well as to the successions of the Apennine margin.

3. Geomorphological map

The geomorphological map of Rio della Rocca valley, created at 1:7500 scale, was obtained by combining, in a geographical information system (GIS) environment, the available geological data with those derived from geomorphological surveys performed from 2009 to 2011 and analysis of multi-temporal aerial photographs. Two sets of aerial photos from 1954 and 1973 (respectively 1:33,000 and 1:15,000), as well as orthophotos from 2008 (50-cm resolution) have been analysed in order to reconstruct the recent geomorphological evolution and to map geomorphological features of the area.

Landforms and processes are depicted on the geomorphological map following the scheme and legend of the Italian mapping methodology (APAT, 2007; Gruppo di lavoro per la cartografia geomorfologica, 1994): the genesis of landforms has been distinguished by using symbols of different colours, and their state of activity has been marked through colour shades, more intense shades being used to depict active landforms and processes (cf. Dramis & Bisci, 1998; Dramis, Guida, & Cestari, 2011; Panizza, 1972; Panizza et al., 2011).

Landforms and processes have been grouped in (i) gravity-induced slope processes and landforms, (ii) fluvial and slope landforms due to running water, (iii) anthropogenic landforms. Bedrock has also been mapped distinguishing the outcropping geological formations by means of full-colours, with tectonic elements also included. The lithological and structural features have been derived from the most recent geological maps of the area available from the Servizio Geologico, Sismico e dei Suoli – Regione Emilia-Romagna (2012) as well as from Gasperi and Preti (2005) and validated by means of field observations.

The 1:5000-scale sheets of the Carta Tecnica Regionale (published by the Emilia-Romagna Region in 1998) were used as a topographic base map.

4. Geomorphological features of the study area

Landforms in the Rio della Rocca valley can be primarily related to gravity-induced, fluvial and anthropogenetic processes.

4.1. *Gravity-induced slope landforms*

The study area is characterised by gravitational processes which have induced the occurrence of different types of landslides, whose distribution is closely related to the geological and geomorphological framework and local relief. Approximately 8.5% of the study area is characterised by landslides affecting fields and meadows, which are mainly ascribable to earth slides and flows. More than 70% of landslides are active and the highest concentration and activity is formed to the western sector where marly and clayey terrains outcrop. Among landslides in the valley, worthy of notice is the translational slide which has affected the south slope of Mount Pradella in 1991 (Figure 4). Predisposing factors can be related to structural features, in particular to the presence of weaker levels within the rock mass, and to quarrying activities nearby. The landslide, occurred during the night between 6 and 7 April 1991, caused the interruption of the excavation activities of the nearby quarry, compromising the entire west side of the excavation front for a length of approximately 220 m (Soldati et al., 2009). Currently, landslide accumulation does not show any clear evidence of activity. Solifluction processes are also widespread, and particularly occur at the foot of the area surrounding the Castello di San Valentino located in the western sector of the study area.

4.2. *Fluvial and slope landforms due to running water*

Erosional landforms related to running water are particularly widespread due to the presence of low permeability and highly erodible lithologies. The study area is characterised by the presence of active badlands shaped in Blue Clays terrain (Figure 5) which are mainly concentrated in the central and northern sectors of the valley. Badlands occupy about 25% of the study area and are characterised by closely spaced V-shaped gullies with steep sides and separated by knife-edged ridges. Small earth and mud flows – whose accumulation extent is too small to be depicted on the geomorphological map – locally fill the erosion furrows at the foot of the badlands. In most cases, these accumulations are stabilised by vegetation.

Figure 5. Panoramic view of active badlands shaped in the Blue Clays in the central sector of the study area (Photo M. Soldati).

The Blue Clay slopes are locally affected by surface runoff and rill wash features have been identified also in the abandoned clay quarries located in the lower zone of the basin.

Inactive alluvial deposits, due to the activity of the main river in the surrounding area (Secchia River) since the Middle Pleistocene have been observed in the eastern part of the watershed, in the vicinity of Cadiroggio and Il Casale villages. These terraced deposits witness the alternating valley floor aggradation and dissection phases as a consequence of climatic and glacio-eustatic changes. Small-sized active alluvial deposits can also be found along the Rio della Rocca riverbed. Peculiar erosional landforms in the form of meanders entrenched in bedrock can be observed in the Rio Campovecchio streambed, carved in the arenaceous-conglomerates lithofacies of the Ranzano Formation, located on the western slope of Monte Pradella.

4.3. *Anthropogenetic landforms*

Although the population density in the valley is scant, human impact on the morphology of the study area cannot be neglected, especially as concerns over the activities carried out in connection with clay pits and sandstone quarries which were active in the area from the mid 1950s (Soldati et al., 2009). The main anthropogenetic landforms are located in the central sector of the catchment, where step-like slopes in abandoned sandstone quarries in the Ranzano Formation (arenaceous-conglomerate lithofacies of Val Pessola Member) are particularly evident (Figure 6). At present only one quarry in the Blue Clays is active. Besides quarries and pits, a motocross field, together with its facilities, has caused profound and significant morphological modifications on the right bank of the Rio della Rocca stream, favouring also slope instability phenomena (Figure 7).

5. Final remarks

The geomorphological map produced provides a comprehensive picture of the distribution of geomorphic processes and landforms of the Rio della Rocca valley. The geomorphological features observable in the valley

Figure 6. A step-like slope in abandoned sandstone quarry in the Ranzano Formation (arenaceous-conglomerate lithofacies) (Photo D. Piacentini).

Figure 7. Panoramic view of north-western sector of the study area: Mount de' Vinci in the background, motocross field and its facilities in the foreground, outcrops of Ranzano Formation (arenaceous-conglomerate lithofacies) on the left (Photo M. Soldati).

derive from the complex interactions of gravitational, running-water and anthropogenetic processes that have controlled landscape evolution in recent time, also determining slopes instability conditions. In particular, human activity in Rio della Rocca valley has been extensive since the mid 1950s, particularly concerning activity carried out in connection with the exploitation of clay and sandstone materials. The study area has been affected by intense quarrying which has largely modified its environmental and geomorphological features. In the 1970s, three clay pits and four sandstone quarries were active in the area. The clay pits were used for tile production whereas the sandstone materials were utilised in large part by the building industry.

This situation has radically changed during the past twenty years, with the abandonment of four quarries as a result of the progressive introduction of ever-more restrictive environmental policies, imposing rigorous planning on mining activities. At present only one quarry is active in the catchment.

The map provides a necessary base document which is fundamental planning the environmental rehabilitation and protection of the area. Based on the geomorphological map, proposals have been made for the design of physical protection measurements to mitigate possible risks. Nature trails have been outlined with the aim of enabling visitors to become acquainted not only with the aesthetic quality of the landscape, but also with its scientific relevance. In this perspective, a recognition and assessment of the geosites in the catchment has been carried out, as a basis for fostering tourism and recreation, as well as the protection of area (cf. Soldati et al., 2009).

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Software

All cartographic design, including the layout, was carried out using the ESRI ArcGIS 8.3. Data collected by field survey and air-photo interpretation have been geo-referenced and digitised. For each mapped landform a database containing attributes has been developed.

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