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STUDENT SECTION

Castel di Sangro-Scontrone field camp – structural and applied geomorphology

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ABSTRACT
The Geomorphological Field Camp 2014 in the Castel di Sangro-Scontrone area is the result of geological and geomorphological teaching field work activities carried out in Central Italy by a group of 23 students attending the Structural Geomorphology and Applied Geomorphology courses (Master's Degree in Geological Science and Technology of the Università degli Studi 'G. d'Annunzio' Chieti-Pescara, Italy, Department of Engineering and Geology). The Field Camp 2014 was organized in May 2014, following regular classes held during the fall term. General activities for the field camp were developed over four main stages: (1) preliminary analysis of the regional geological and geomorphological setting of the area; (2) preliminary activities for the analysis of the local area (orography, hydrography and photogeology investigations, and geographical information system processing); (3) field work, focused on the analysis of a specific issue concerning structural geomorphology or applied geomorphology (e.g. landscape evolution, river channel change, landslide distribution, and flood hazard); and (4) post-field work production of the map. Finally, the fundamental role of field work in the analysis of landscape and in land management was outlined: indeed, the overall field camp enhanced the crucial role of field-based learning for young geomorphologists in order to acquire a strong sensitivity to geomorphological processes and landscape evolution.

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Structural geomorphology; applied geomorphology; field work; students; central Italy; Scontrone; Castel di Sangro

1. Introduction

The Geomorphological Field Camp in the Castel di Sangro-Scontrone area is the result of >25-year geological and geomorphological field work activities carried out in Central Italy by university tutors for research and teaching purposes. This map is the result of geomorphological field work carried out by a group of 23 students attending the Structural Geomorphology (7) and Applied Geomorphology (16) courses held as part of the Master's Degree in Geological Science and Technology of the Università degli Studi 'G. d'Annunzio' Chieti-Pescara (Italy), Department of Engineering and Geology.

Educational field work activities have been completed by the tutors across Central Italy, from coast to mountains, at different University sites and as part of several projects in collaboration with the Geological Survey of Italy and the Abruzzo Region (CARG Project, IFFI Project; ISPRA, 2007a, 2007b, 2010a, 2010b, 2010c, 2010d). Field work experience in Italy was compared and integrated with field work in other countries such as Japan, Ethiopia, and Svalbard.

These continuous activities have strengthened the awareness of the power of field observation, survey, and mapping for the comprehension of natural processes at different spatial and temporal scales: from the long-term landscape evolution of a mountain chain, a single ridge or basin or slope (concerning structural geomorphology), to the short-term incision or flooding of a river, the development of a landslide or coastal retreat inducing geomorphological hazards. This has encouraged constant efforts in teaching field work activities to young geologists, trying to combine contemporary hardware and software tools provided by technological advancements with traditional field methods.

The Geomorphological Field Camp 2014 was organized in May 2014 for three days of field work in the Castel di Sangro-Scontrone area (upper part of the Main Map), following regular classes held during the 2013 fall term. The study area was chosen because of its peculiar geological features and because it is affected by geomorphological hazards due to landslides and flooding, as well as by complex and long-term landscape evolution.

2. Field camp organization

Activities were carried out by all students, divided into seven working groups of three to four persons each, in four main stages. These were:

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- preliminary desktop analysis (pre-field camp) of the regional geological and geomorphological setting;
- preliminary desktop analysis (pre-field camp) of the local study area;
- field work activities (during the three-day field camp) focused on the solution of a specific structural or applied geomorphological issue; and
- final mapping work (post-field camp) for the production of the overall geomorphological map including the contribution of all the groups.

For analysis of the regional geological and geomorphological setting, each group was provided with the base geological and topographic maps and digital elevation models (DEM) of the River Sangro basin, as well as with several scientific articles about the regional setting. Each group collected and studied a complete list of references, including methodological scientific articles, regional and local geology and geomorphology, technical geological and geomorphological documentation, and cartography. The collected data were processed using Esri ArcGIS 10.1, producing the main orography, hydrography, and geology data sets for the regional area surrounding the Castel di Sangro basin.

The analysis of the local study area was also based on orography, hydrography, and photogeology investigation through geographical information system (GIS) processing of detailed topographic maps and DEMs, digitization of the drainage network, and aerial photo interpretation. Aerial photo interpretation focused on multi-temporal geomorphological mapping of channel adjustments using 1:33,000 (Abruzzo Region, 1987; Flight Abruzzo, 1982-1987; Flight GAI, IGMI, 1954) and 1:5000 scale aerial photos, as well as orthophotos (AGEA Abruzzo Region, 2013, retrieved from http://opendata.regione.abruzzo.it/catalog).

For field work, each of the seven groups were assigned a specific topic (Table 1) and field survey area (see the Main Map). Geomorphological field mapping was carried out at a 1:5000 scale by each group in its specific field area, investigating the outcropping bedrock lithology, tectonic features, superficial deposits, and the different types of landforms (structural, slope, fluvial, and anthropogenic) using a common legend. Field mapping was performed in accordance with the guidelines of the Geological Survey of Italy (ISPRA, 2007c, 2009; SGN, 1992, 1994), the IFFI project (ISPRA, 2007a, 2007b), the PAI project (Abruzzo-Sangro Basin Authority, 2005), and the geomorphological mapping literature and conventions (e.g. Dramis, Guida, & Cestari, 2011; GNGFG, 1994; Miccadei, Orrù, Piacentini, Mascioli, & Puliga, 2012a, 2012b, 2013; Miccadei, Paron, & Piacentini, 2004; Otto, Gustavsson, & Geilhausen, 2011; Piacentini, Sciarra, Miccadei, & Urbano, 2015; Piacentini, Urbano, Sciarra, Schipani, & Miccadei, 2015; Santo et al., 2014; Smith, Paron, & Griffiths, 2011). After the field work, each group presented a 1:5000 geomorphological map of the field investigation area and a discussion of the specific topic. All the results were then summarized, producing an overall geomorphological map (1:16,500 scale).

Table 1. Specific geomorphological topic for each group.

	Applied geomorphology
Group 1	Soil erosion in the Montagna Spaccata Lake area
Group 3	Lithology – landslides relationship in the SE side of the Castel di Sangro plain
Group 2	Definition of flood areas in the SW side of the Castel di Sangro plain and possible mitigation measures
Group 5	Definition of flood areas in the central part of the Castel di Sangro plain and possible mitigation measures
Group 7	Definition of flood areas in the NE part of the Castel di Sangro plain and possible mitigation measures
	Structural geomorphology
Group 4	Definition of morphostructural elements on the NW side of the Castel di Sangro plain
Group 6	Site selection for a new school building

3. Study area: Castel di Sangro plain

The Castel di Sangro-Scontrone area is an intermontane plain located in the Central Apennines, in southern Abruzzo, at the border with the Molise Region. The area is characterized by a wide Pleistocene–Holocene fluvial plain between the upper and middle part of the Sangro River valley (upper part of the map), one of the main rivers of the Adriatic side of Central Italy, surrounded by carbonate ridges to the NW and by ridges on alternating calcareous-marly and pelitic-arenaceous rocks to the SE.

The area is characterized by 1–2.5 km wide and >8 km long fluvial plain at the transition between the upper and middle Sangro River valley (upper part of the map). The plain is 800–900 m a.s.l., with surrounding ridges up to >2000 m (Figure 1), and lies in a complex geological and geomorphological setting between the Abruzzo Apennines, characterized by thrust and anticline ridges and faulted homocline ridges, and the Molise Apennines, mostly characterized by fault thrust ridges, isolated relief, hogback, and cuesta relief (Ascione, Cinque, Miccadei, Villani, & Berti, 2008; Clermonté, 1977; D'Alessandro, Miccadei, & Piacentini, 2003; Vezzani & Ghisetti, 1998).

On the southern side of the plain, the bedrock is made up of Cretaceous-to-Miocene marly and calcareous rocks pertaining to the Molise pelagic units, overlain by pelitic and arenaceous-pelitic successions (Flysch di Agnone formation, *Auctt.*). On the northern side of the plain, the bedrock is made up of Jurassic-Cretaceous calcareous successions pertaining to the Morrone-Pizzalto-Rotella carbonate platform and the related shelf and scarp (Miccadei, 1993; Patacca & Scandone, 2007).

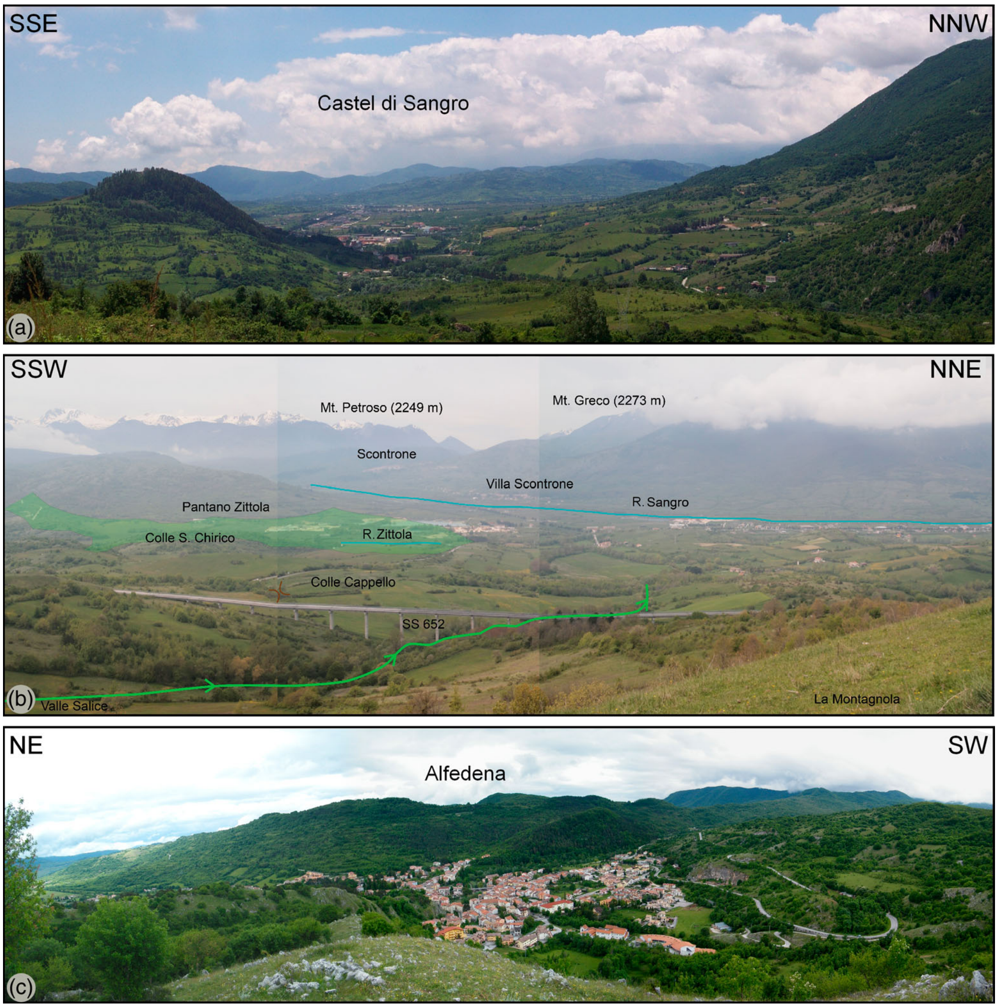


Figure 1. Panoramic view of the Castel di Sangro plain. (a) Alfedena and Rio Torto stream area (SW side of the plain); (b) central area of the plain (from SE); (c) northeastern part of the plain (from NE).

The plain is partly covered by continental deposits: slope deposits and alluvial fan along the margins of the plain and fluvial deposits within the plain. The fluvial deposits are arranged in at least four orders of terraces, while the slope deposits belong to two different generations. Their age ranges from the Lower-Middle Pleistocene to the Holocene (Capelli, Miccadei, & Raffi, 1997; Piacentini & Miccade, 2014).

The geomorphological analysis has outlined landforms and deposits related to gravitational processes along the slopes surrounding the basin, such as talus slopes and breccia deposits, arranged in different entrenched units (northern side), and several landslides involving clayey, marly, and arenaceous lithologies (southern side). Fluvial landforms characterize the central part and sides of the plain with fluvial erosion scarps and terrace scarps; gully erosion affects the slopes surrounding the plain. The formation and evolution of the basin is related to the erosional processes on the soft (clayey and arenaceous) lithologies, with no evidence of recent tectonic activity. The fluvial plain of the Sangro River has undergone significant change over the last few decades, due to natural and anthropogenic factors (Schipani, 2003).

4. Morphometric analysis

A morphometric analysis of the orography and hydrography of the upper part of the River Sangro basin was carried out as part of the preliminary activities and allowed an outline of the landscape of the area to be completed and to introduce the geomorphological field work. The analysis was based on the topographic maps and the Abruzzo Region DEM (40 m pixel resolution, http://opendata.regione.abruzzo.it/catalog), as well as the ASTER GDEM for the Molise area (30 m pixel resolution, http://asterweb.jpl.nasa.gov/gdem.asp). The parameters of orography and hydrography were calculated through the GIS, using a range of spatial analysis tools for orography, and with semiautomatic procedures, for hydrography (drainage network and basins manual digitizing, automatic calculation of areas and lengths, parameters processing with spreadsheets).

The main morphometric indices were calculated (Avena, Giuliano, & Lupia Palmieri, 1967; Ciccacci, D'Alessandro, Fredi, & Lupia Palmieri, 1989; Ciccacci, Del Monte, Fredi, & Lupia Palmieri, 1995; Horton, 1932, 1945; Schumm, 1956; Strahler, 1952, 1957) and

Table 2. Main morphometric indices calculated.

Linear indexes	Bifurcation ratio	$R_b = \frac{N_u}{N_{u+1}}$	The ratio between the number of streams (N) in a given order (u) to the number of streams in the next higher order (u+1)
	Hierarchical anomaly number	$G_a = \sum_{i=1}^{s-2} \sum_{r=i+2}^{s} N^*_{i,r} f_{i,r}$	The minimum number of the first order streams required for a complete hierarchization of the drainage network
	Density (g_a) and index (Δ_a)of hierarchical anomaly	$g_a = \frac{G_a}{A}$ $\Delta_a = \frac{G_a}{N_1}$	The ratio between the hierarchical anomaly number and area of the basin (*Density* g_a) or the number of the first order streams (*Index* Δ_a)
Areal indexes	Circularity ratio	$C = \frac{4\pi A}{p^2}$	Dimensionless, it is a function of the basin area (A) and of the area of a circle with same perimeter of the basin (p); range 0–1 It outlines the degree of circularity of the basin; it depends on the stream flow in the watershed and is influenced by the length and frequency of streams, geological structures, land use/ land cover, climate and slope of the basin
	Form factor	$F = \frac{A}{L^2}$	Dimensionless, ratio between the basin area (A) and the square of the basin length (L); range 0–1 Quantitative expression of the drainage basin outline; a value higher than 0.78 indicates a circular basin, smaller values suggest the elongated form of the basin
	Elongation ratio	$E = \frac{2\sqrt{\frac{A}{\pi}}}{L}$	Dimensionless, defined as the ratio of the diameter of a circle of the same area (A) as the drainage basin to the maximum length of the basin (L); range 0–1; it outlines the elongation of a basin
	Drainage density	$\Delta = \frac{L_{tot}}{A}$	Ratio between the total stream length within the basin and the basin area; it is a measure of how well or how poorly a watershed is drained by stream channels
	Drainage frequency	$Fr = \frac{N}{A}$	Obtained by dividing the total number of stream segments of all orders by the total drainage area Stream frequency indicates a positive correlation with drainage density, suggesting an increase in stream population with an increase in drainage density. Stream frequency reflects the texture of the drainage density

are shown in Table 2. The indirect estimation of the average long-term erosion rate was calculated based on drainage network morphometry, using drainage density and hierarchical anomaly of the drainage (according to Ciccacci, D'Alessandro, Fredi, & Lupia Palmieri, 1992).

In addition, orographic (Figure 2) and hydrographic (Figures 3 and 4) maps were produced, outlining the overall orographic and physiographic features of the upper River Sangro basin.

5. Geomorphological field work

The field work carried out during the three-day field camp by each group allowed students to increase their understanding of field analysis and classification of landforms related to different processes, particularly focusing on the specific topic assigned. The results of the field work of each group was then compared to the other groups in order to allow an overall comprehension of the geomorphological features of the Castel di Sangro Plain. The results of the work of all the groups were then merged in the post-field work GIS activities and summarized on the main geomorphological map. This allowed students to be aware of the different steps in the production of a geomorphological map resulting from the contributions of several working groups.

On the map, the following lithological and geomorphological elements are included.

(1) *Lithologies* are subdivided into bedrock and superficial deposits (Figure 5).
   (a) *Bedrock units* are divided in to *calcareous bedrock* and *pelitic-arenaceous bedrock*. The first includes all calcareous formations outcropping in the study area pertaining to the Mesozoic-Cenozoic carbonate platform and shelf sequence (NW side of the Sangro valley) and the marly-calcareous units pertaining to the Molise pelagic sequences (SE side of the Sangro valley). The *pelitic-arenaceous bedrock* consists of Neogene flysch-like deposits (i. e. Flysch di Agnone, Gran Sasso-Genzana flysh; Di Bucci, Corrado, Naso, Parotto, & Praturlon, 1999; Patacca & Scandone, 2007).
   (b) *Superficial deposits* are subdivided according to their morphogenetic process; cemented and loose scree-slope deposits, colluvial deposits, landslide deposits, fluvial deposits, terraced fluvial deposits, alluvial fan deposits, and backfill deposits are identified (Capelli et al., 1997). Fluvial deposits and terraced fluvial deposits are the most widespread within the whole Castel di Sangro plain and the northwestern flank.

(2) The *geomorphological features* of the study area are classified according to their origin: structural landforms, slope-gravity landforms, fluvial landforms, karst landforms, and anthropogenic landforms (Figure 6).
   (a) *Structural landforms* are influenced by the different outcropping lithologies and their mutual spatial and stratigraphic relationships. Fault line scarps can be observed along the carbonate ridges (as well as saddles) west of the village of Alfedena and on the NW slope of the plain. The SE and SW sides of the plain are characterized by ridges and saddles. Fault

line scarps related to low-angle thrust faults are also present in the Castel di Sangro area.

(b) *Gravity-induced landforms* are represented by mass movements that develop on slopes bordering the Sangro valley and locally by talus slopes. Several types of mass movements are recognized (classification according to Cruden & Varnes, 1996): rock falls (on calcareous bedrock, mostly on the southern and west sides of the valley and locally in the Castel di Sangro area), earth flows, translational slides, and soil creep (on pelitic-arenaceous bedrock, mostly on the SE side of the plain).

(c) *Fluvial landforms* are common in the study area along the plain. Alluvial fans are present in the SW Alfedena area and on the northern side of the plain. Fluvial gorges, from 10 to 30 m deep, characterize the SW side of the plain. Within the Sangro plain, fluvial deposits as well as alluvial fans are arranged in four orders of terraces (up to 80 m above the present channel). The higher terraces, made of coarse (pebbles, cobbles, and boulders) deposits, are preserved in small remnants on the left side of the valley, while the lower terraces, made of medium to coarse (sands, pebbles, cobbles, and boulders) deposits, are well developed and continuous along the plain, outlining the progressive long-term incision of the plain itself. Several fluvial scarps (2–3 m up to >20 m high) are present along the Sangro channel and floodplain (locally affected by lateral erosion and down-cutting), outlining recent dynamics of the plain. The fluvial channel shows strong variability from SW to NE in terms of width, channel type, landforms, and anthropization, outlined by abandoned braided channels, due to recent natural and anthropogenic changes (see Section 6).

(d) *Anthropogenic landforms* are primarily concentrated near urban areas, along the main roads and railway lines, and along the Sangro channel. They are represented by backfill, quarry, scarps, bank protection, and dams, as well as by the alignment of the Sangro channel.

6. Geomorphological issues

The integration of preliminary regional and local activities and geomorphological field work activities allowed each student group to analyze and discuss the specific applied and structural geomorphology topic assigned and in general to be aware of the role of field geomorphology in the solution of specific issues.

6.1. Soil erosion in the Montagna Spaccata lake area

This analysis was based on a detailed geological and geomorphological survey (scale 1:5000) of the upper Rio Torto basin (right tributary of the Sangro River) and direct estimate of the gully and channel size and erosion features, compared with preliminary indirect estimate (see Section 4) in order to quantitatively assess soil erosion and to evaluate sediment filling of the Montagna Spaccata dam reservoir.

At an early stage, the following orographic and hydrographic parameters of the basin were calculated: drainage network and basin map, longitudinal and transverse profile (of gullies and channels) and the orography, slope distribution, aspect, and land use of the valleys.

Gully and erosion channel sizes were measured for the calculation of potential soil erosion. The sum of the potential soil erosion for each sub-basin defined the soil erosion in the basin upstream of the lake (Figure 7). This field-based estimation was then compared with the results of the drainage morphometry-based calculation (see Section 4; according to Ciccacci et al., 1992) in order to obtain an assessment of soil erosion and an estimate of the lake's sediment filling.

6.2. Lithology – landslide relationships on the SE side of the Castel di Sangro plain

This analysis focused on the SE side of the Castel di Sangro plain, between the northern side of the Colle Alto (NW of Montenero Val Cocchiara, IS) and the Sangro River, and was based on a field survey of landslides.

The majority of landslides are found in the southern portion of the study area, along the northern side of the Colle Alto, where calcareous bedrock, mainly consisting of marly limestones (upper part of the slope), overthrusts the pelitic-arenaceous bedrock, consisting of a clay-silt facies (lower part of the slope), as outlined by a sharp slope break.

On the upper part of the slope, mostly small translational slides occur on fracturated calcareous bedrock. On the lower part of the slope, large complex landslides occur from the boundary between the calcareous and pelitic-arenaceous bedrock down to the base of the slope. These are ancient inactive landslides with a smooth scarp, whose accumulation is affected by fluvial erosion and by small landslides such as superficial earth flows and soil creep.

All along the fluvial plain, consisting of recent and terraced gravel deposits, no landslides were observed, except for some small failures along the terrace scarps and the fluvial scarps.

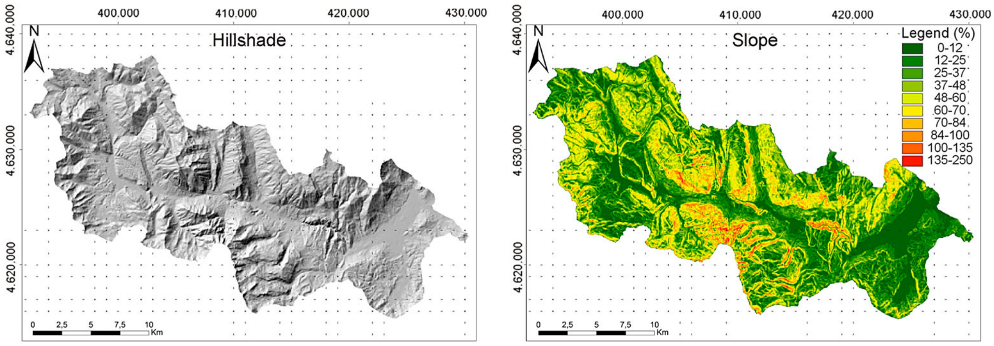


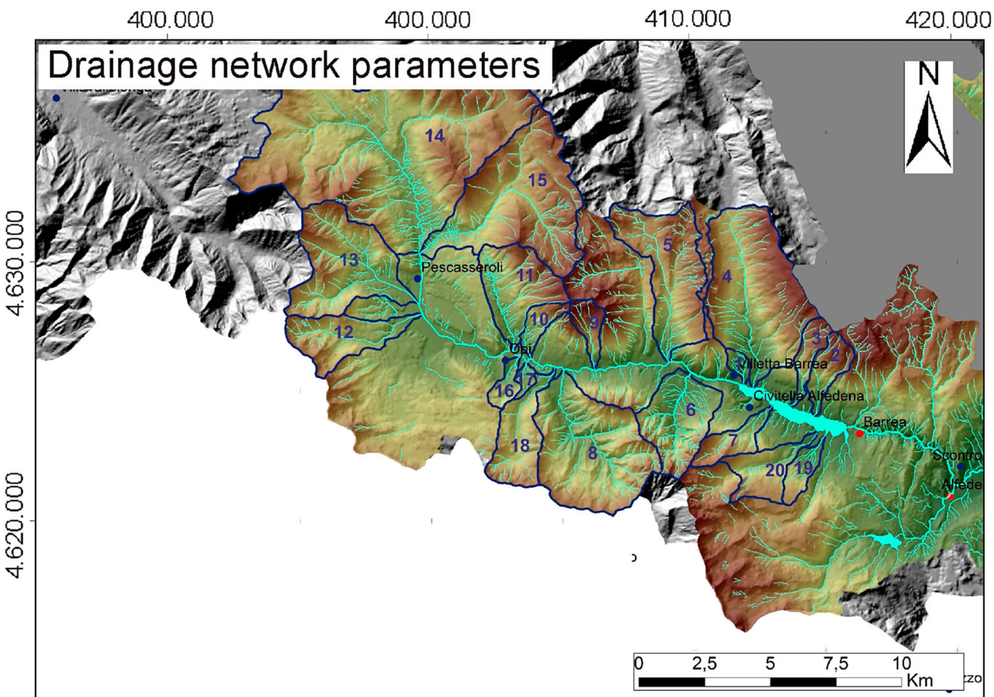
Figure 2. Orography of the upper Sangro River basin: hillshade and slope.

6.3. Recent channel adjustments in the sangro river

This analysis was based on a multi-temporal investigation of aerial photos compared with field mapping in order to evaluate the recent evolution of the Sangro riverbed along the Castel di Sangro plain, in terms of channel type and width.

The interpretation was made on 1955 aerial photos (IGMI, 1955), 1985 aerial photos (Abruzzo Region, 1985), and a 2013 orthophoto (Abruzzo Region AGEA, 2013); the river channel and floodplain related to each image were digitized and compared (lower part of the map).

- *1955*. The channel appears to have a mainly braided riverbed and some secondary sinuous and straight reaches. The braided reach is observed from 2 to 6 km downstream of Villa Scontrone. The bank full river channel appears to be wider (up to >500 m) in the downstream reach than in the upstream one (~200 m), showing poor vegetation cover.
- *1985*. The images show the artificial canalization of the riverbed from 2 km downstream of Villa



Linear parameters	SB 1	SB 2	SB 3	SB 4	SB 5	SB 6	SB 7	SB 8	SB 9	SB 10	SB 11	SB 12	SB 13	SB 14	SB 15	SB 16	SB 17	SB 18	SB 19	SB 20
hierarchical order	3	3	3	3	4	4	2	4	3	3	4	3	4	4	4	3	3	3	3	2
bifurcation ratio	3,375	2,66	2,83	8,77	5,51	3,56	3,5	3,29	3	3,33	4,07	4,4	3	6,05	5,14	3	2,66	2,5	2,66	7
bifurcation index	2,625	2	2,33	4,14	3,33	2,51	3	3,42	2,75	2,66	2,86	2,6	3	4,61	2,89	2,25	2,5	2	2,66	5
	0,75	0,66	0,5	4,63	2,17	1,05	0,5	1,44	0,25	0,66	1,32	1,8	1,73	1,65	3,37	0,75	0,16	1,35	0	2
hierarchical anomaly	3	3	0	14	6	25	0	52	1	2	56	4	15	66	93	2	0	1	0	0
hier. anomaly density	3,98	1,08	0	0,74	0,5	3,12	0	2,96	0,51	1,12	7,23	0,62	1,15	1,31	4,56	1,47	0	0,17	0	0
hier. anomaly index	0,27	0,43	0	0,19	0,07	0,25	0	0,63	0,12	0,18	0,83	0,21	0,25	0,4	0,81	0,25	0	0,05	0	0
Areal parameters																				
area	0,753	2,78	2,17	18,89	12,04	8,01	2,82	17,54	1,96	1,78	7,75	6,4	13	50,47	20,4	1,36	0,64	5,9	1,96	4,26
circularity ratio	0,67	0,51	0,37	0,62	0,4	0,68	0,43	0,7	0,47	0,47	0,59	0,43	0,51	0,45	0,45	0,52	0,49	0,42	0,49	0,37
form factor	0,32	0,25	0,16	0,39	0,31	0,47	0,18	0,5	0,25	0,24	0,44	0,24	0,4	1,03	0,4	0,29	0,27	0,24	0,21	0,23
elongation ratio	0,64	0,57	0,45	0,7	0,63	0,77	0,48	0,8	0,57	0,55	0,75	0,55	0,71	1,14	0,71	0,61	0,59	0,55	0,52	0,54
drainage fequency	21,25	3,95	5,52	4,45	9,3	16,84	6,38	6,27	5,6	8,4	11,62	3,91	6	4,32	6,81	8,08	17,15	4,74	5,59	1,88
drainage density	6,66	3,26	4,18	2,46	3,14	5,01	3,02	2,78	3,3	3,15	4,33	2,29	2,81	1,91	2,62	2,51	4,13	2,11	3,73	1,68

Figure 3. Hydrography of the upper Sangro River basin: drainage network, sub-basins and main geomorphic parameters.

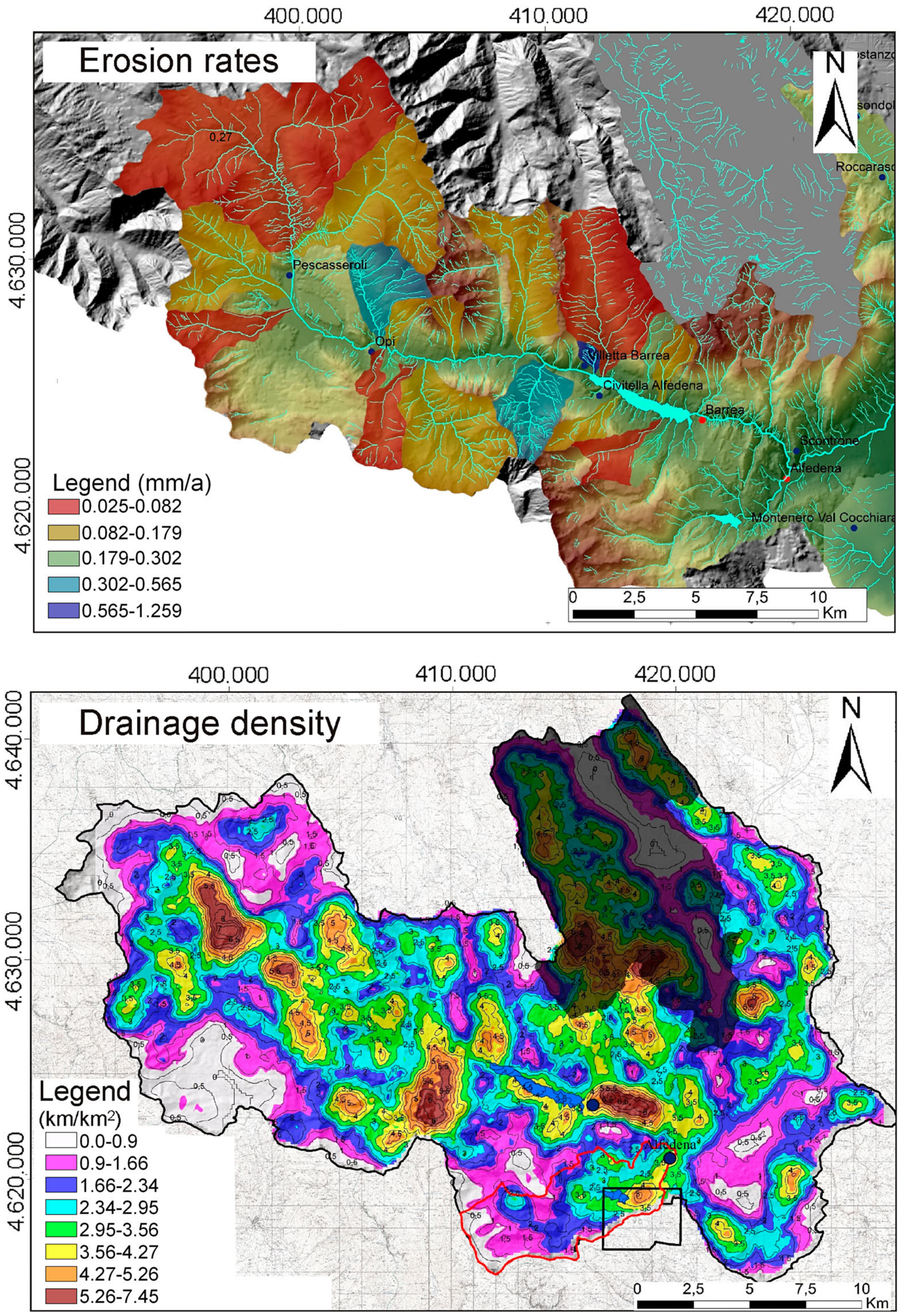


Figure 4. Hydrography of the upper Sangro River basin: estimated erosion rates (according to Ciccacci et al., 1989, 1992) and drainage density (calculated on a 500 m radius moving window).

Scontrone to Castel di Sangro. The anthropogenic intervention has aligned the riverbed, strongly reducing the floodplain area (<100 m wide) when compared to 1955; the upper reach is also slightly reduced to <200 m. A general increase in vegetation cover is observed along the former river banks (see also Schipani, 2003).

- *2013*. Further extension of the artificial canalization is observed near Castel di Sangro, reducing the floodplain zone (again <100 m wide), while the upper reach is still reduced in width (<200 m) and increased in term of sinuosity. A large increase in vegetation cover is observed from 1985 on the plain delimited by the bank full channel.

All these considerations suggest an increase in the vertical incision, which is supported by the consequences of the 1991 flood (Capelli et al., 1997) that caused damage to the artificial channel and required excavation.

Figure 5. Field work activities and lithologies characterizing the study area. (a) Alfedena area, calcareous bedrock, moderate to high fracturation; (b) SE side of the Sangro plain, bedding on the calcareous bedrock (N55E/25SE); (c) SE side of the Sangro plain, high fracturation and cataclasite on the calcareous bedrock; (d) Castel di Sangro area, pelitic-arenaceous bedrock; (e) Castel di Sangro area, terraced fluvial deposits, made up of conglomerates with sand lenses; (f) Alfedena area, alluvial fan deposits.

6.4. Flood areas in the SW, central and NE part of the Castel di Sangro plain

The study is based on multi-temporal photo interpretation and field work, compared with hydrological data. The riverbed has been heavily shaped by human intervention for decades, with extensive modification of its natural features (i.e. alignment, channel width reduction, industrial activities, and urbanization on the floodplain). The data show that the construction of the artificial channel along the Sangro valley (in the 1980s), from Villa Scontrone to Castel di Sangro, is one of the most important elements that have influenced the evolution of the channel's physical environment and its vulnerability to hydrogelogic instability (see also Section 6.3 and Schipani, 2003, 2006). Moreover, the field work has allowed the identification of fluvial terraces or fluvial, anthropogenic and polygenic scarps, which have resulted in better definition of the flood area boundaries.

The potential flood areas (Figure 8) were defined taking into account a 7 m-high water level above the river bed, as occurred in the 1991 Sangro flood event, which had a discharge of 700 m^3/s (Capelli et al., 1997). The areas affect locally Alfedena, whilst more widely the central part of the plain and the Castel di Sangro area.

6.5. Definition of morphostructural elements on the NW side of the Castel di Sangro plain

Field work identified a NE–SW tectonic alignment characterized by the en-echelon structure of transcurrent faults. The strike of these faults is N20E, with their surface expression shown by several structural scarplets.

Mutual relationships between superficial deposits and tectonic alignments were analyzed through a geomorphological cross section (Figure 9). The dip-slope Late-Middle Pleistocene breccia do not show any

Figure 6. Field work activities and landforms characterizing the study area. (a) Alfedena area, fault line scarp; (b) SE side of the Sangro plain, structural surface; (c) Castel di Sangro area, main Sangro River channel; (d) SE side of the Sangro plain, alluvial fan and alluvial plain; (e) Castel di Sangro area, landslide deposit made up of large calcareous blocks; (f) Castel di Sangro area, artificial channel and main bank protection.

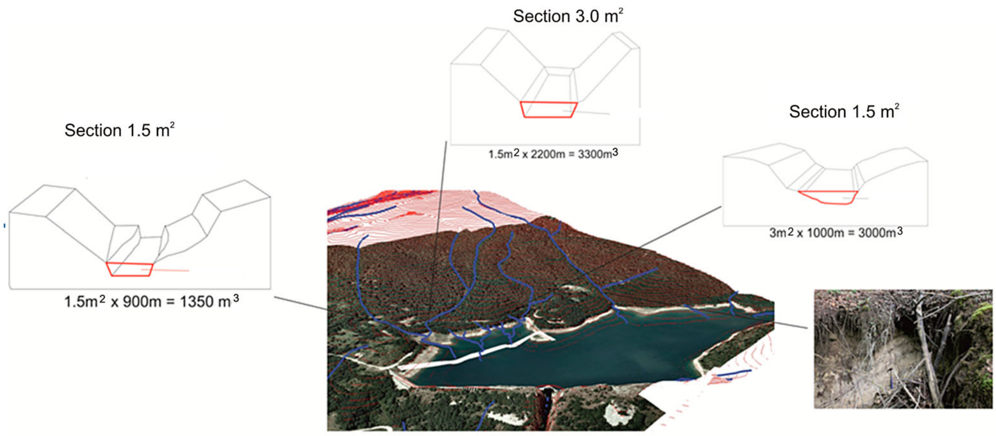


Figure 7. Evaluation of sediment contribution in the Montagna Spaccata lake; the main gullies of three streams were detected and measured during field surveys.

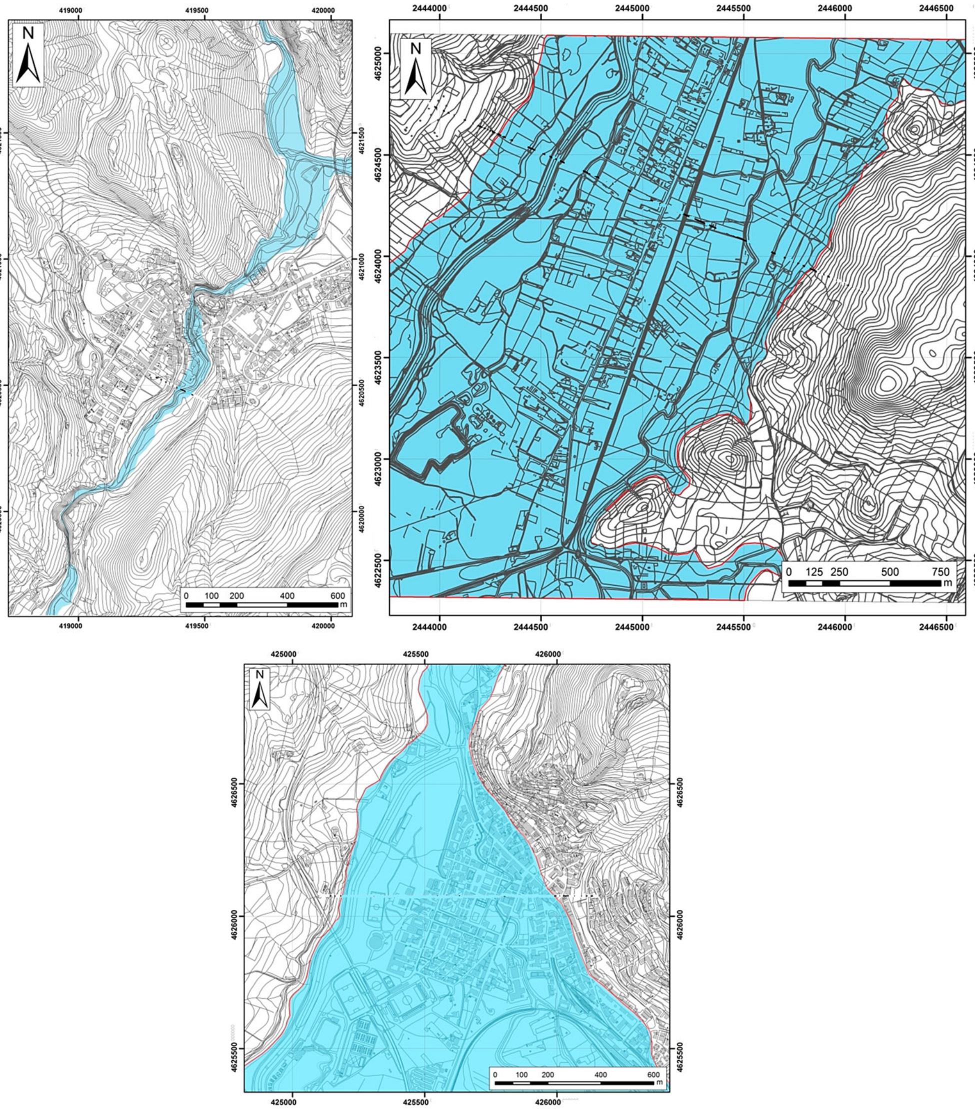


Figure 8. Flood areas in the SW (a), central (b) and NE (c) part of the Castel di Sangro plain.

significant evidence of rotation or faulting; the strike is ≈N20E, while the dip is 20–25° SE.

From this work it is possible to define the scarps as fault line scarps which predate fault activity before breccia deposition along the slope. As a consequence, the activity of these faults is dated before the Late-Middle Pleistocene.

6.6. Site selection for a new school building

The area investigated was on the southeastern side of the Castel di Sangro plain and in the Pantano Zittola area. After careful field survey, we concluded that the most suitable area is on an alluvial deposit, in terms of lithology and geomorphological processes (no

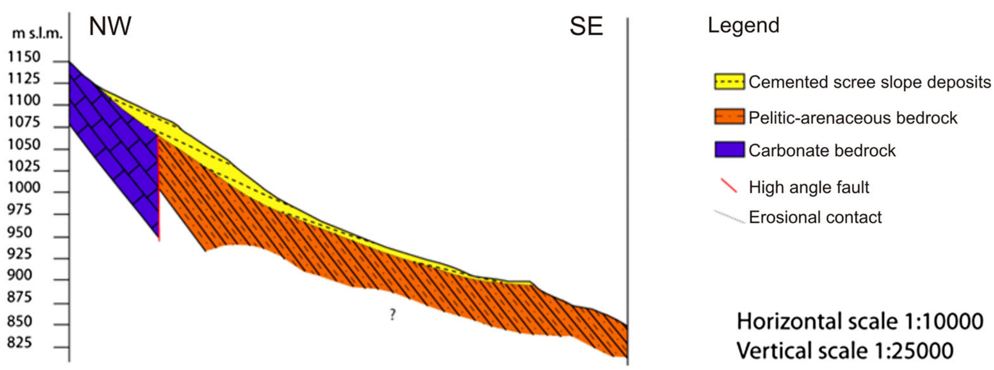


Figure 9. Morphotectonic cross section of the NW side of the Castel di Sangro plain.

slope processes, no floods expected, and no morphotectonic elements).

7. Conclusion

This work aims to enhance the growing legacy of field-based learning for young geomorphologists (Thornbush, Allen, & Fitzpatrick, 2014), allowing them to acquire a strong understanding of geomorphological processes and landscape evolution. The geomorphological mapping and issues outlined here are the result of the Geomorphological Field Camp 2014 in the Castel di Sangro-Scontrone area carried out by a group of 23 students attending the Structural Geomorphology and Applied Geomorphology courses of the Master's Degree in Geological Science and Technology of the Università degli Studi 'G. d'Annunzio' Chieti-Pescara (Italy), Department of Engineering and Geology.

Activities started at the end of regular classes and were focused on (1) preliminary desktop analysis of the regional physiographic, geologic, and geomorphologic setting of the upper River Sangro basin surrounding the study area, (2) preliminary desktop analysis of the orographic, hydrographic, photogeologic, and geologic setting of the local study area, the Castel di Sangro plain, based upon existing literature and topographic maps/aerial photo/DEM analysis, (3) geomorphological field work carried out during a three-day period; and (4) final GIS mapping work activities for the production of the geomorphological map resulting from the contribution of all student groups.

Preliminary activities allowed an outline of the main geomorphological issues that characterize the Castel di Sangro plain in terms of structural geomorphology and applied geomorphology, introducing the geomorphological field work. The field work activities increased the awareness of the participant to geomorphological mapping and improved their skills in focusing field work on a specific issue (i.e. more detailed understanding of constraints to the local landscape evolution, recent natural and anthropogenic river channel changes, landslide distribution, and flood hazard).

The comparison and discussion of the results of the different groups and the overall work carried out for the production of the geomorphological map of the Castel di Sangro-Scontrone area allowed the participant to be aware of the different stages of a geomorphological project and in general of group work and to better comprehend the role of geomorphology in the solution of specific applied issues or more general structural issues. Finally, the analyses carried out in the different stages enhanced the crucial role of field-based learning for young geomorphologists in order to acquire a strong awareness of geomorphological processes, landscape evolution, and land management.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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Software

Maps throughout this work were created using Esri ArcGIS® 10.1.

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