THE VALNERINA GEOLOGICAL PARK

A guide to the exploration

Notes: Stratigraphy, Tectonics, Geomorphology, Quaternary Geology, Georesources.

The Umbria - Marche Apennines, for stratigraphic and tectonic characters, is one of the most studied and visited regions by geologists of all world. Schools and universities bring their students for tracking exercises or follow guided, using this area as a real gym.

The Valnerina is an area of particular value, which collects a multiplicity of sites of scientific interest, representative of the main topics of geology, all fairly easy to reach, thanks to the extension of the network of roads and trails. A territory that for these reasons fully deserves the connotation of geological park.

In this guide, we provide a brief description of the area and of the very interesting sites (geosites), organized into 10 thematic itineraries. The guide is addressed to teachers who want to lead their students to explore this territory, using it as an open-air laboratory. At the same time, the guide can be used by geologists and geology enthusiasts, as the basis for the organization of geotourist excursions. The visit will enrich to the historical-cultural heritage and natural beauty of this region and the excellent quality of the reception.

The "reading tips" provided for each theme, and the bibliography, placed at the end of the volume, can compensate for the schematic treatise due to scarcity of space.

Have a nice trip,

Massimiliano Barchi and Fausto Pazzaglia

1 GEOGRAPHIC and GEOMORPHOLOGIC FRAMEWORK

The Valnerina Geological Park (southeastern Umbria), spreads between the Spoleto and the Sibillini Mountains(fig. 1).

The majority of the geosites described in this guide, developing between the Nera River and the Corno River, around the Group of Coscerno Mt. (1684 m.) - Civitella Mt. (1565 m.), are located on the western part of the Park. The main peaks, excluding the chain of the Sibillini Mountains and those surrounding the plans of Castelluccio, are Coscerno Mt. (1684 m.), Aspra Mt. (1652 m.), Civitella Mt. (1565 m.), Birbone Mt. (1501 m.), Sciudri Mt. (1427 m.), Maggio Mt. (1415 m.), Aspro Mt. (1401 m.), Carpenale Mt. (1384 m.) and Galenne Mt. (1246 m.).

These reliefs are aligned in the direction approximately North-South, according to three main ridges. These are, from West to East, the ridges of Galenne-Solenne-Ferentillo Mts, Coscerno – Aspra Mts and Aspro – Monteleone di Spoleto Mts.

These mountains have generally sweet and rounded tops. These sweet shapes of the summits contrast with the steep slopes (with gradients higher than 1000 m) and with the subvertical cliffs. These rugged forms reflect the strong lifting, still ongoing, suffered by the region in the Quaternary.

The main rivers are the Nera River and its major tributaries, Corno River left hand tributaries and Vigi River in right. The Nera flows from North-East to South-West, Vigi from North to South and the Corno from South to North. Regarding the secondary hydrography, the most important watercourse is the Sordo River, tributary of Corno River and Tissino creek. The waterways are characterized by different flow regimes that produce erosive sediments with very heterogeneous granulometries.

At some plateaus, the hydrographic network has not yet hired a defined trend. Small and large endorheic areas (without emissaries) are observed at some intermontane troughs, as the Pian delle Melette and plans of Castelluccio.

Fig. 1-Orography and hydrography of Valnerina Geological park.

Reading tips

For approaching to the geology of the Umbria-Marche Apennines, the recent " Le Montagne di San Francesco" of Alvarez W. (2010) provides an simple and charming overview about the geological evolution of the region, interspersed by personal anecdotes and historical information. Perfectly appropriate, the monumental "Descrizione Geologica dell'Umbria" of Lotti (1926), also useful to understand the practiced geology 100 years ago. The two volumes of the Guide Geologiche Regionali of S.G.I. (Passeri, 1994; 1997) offer numerous opportunities for geological routes by car (vol. 1) or walk (vol. 2) between Umbria and the Marche.

2 STRATIGRAPHY

The sedimentary sequence outcropping in the area of the Park is typical of the Umbria-Marche basin, consisting of sedimentary rocks formed in a marine environment and placed between the early Jurassic and early Miocene.

The sedimentary units can be grouped into:

- An upper part (from the base of the Maiolica to the Bisciaro Fms) sedimented in the range upper Jurassic-Miocene (150-18 million years ago), that exhibits characteristics relatively homogeneous thickness (except thickening in the southeastern sector due to the presence of intercalations, debris from the coeval Laziale-Abruzzese carbonate platform), concerning a pelagic marine environments and increasingly rich of the clayey component;

-a lower part (from the base of the Calcare Massiccio to the Maiolica Fms.), deposited in the Jurassic (between 150 and 200 million years ago), which is characterized by considerable variability in characteristics of depositional environments (platform, escarpment) and in the thickness of the formations.

The oldest rocks outcropping in the area (Calcare Massiccio Fms., lower Jurassic) testify to the presence of a shallow marine environment, with calm and warm waters, typical of a well oxygenated carbonate platform with algae and mollusks.

At the end of the early Jurassic, an intense tectonic activity broke up this platform and produced ups and downs structural rimmed by faults (Horst and Graben). The rotation of blocks caused the differentiation of the bathymetry of the basin and consequently, the accumulated sediments show different thicknesses and characteristics.

In the lower areas (Graben), the deposits reached greater thickness with characteristics typical of deeper environments. Conversely, above the Horst the successions have characterised by condensed sequences, with the presence of stratigraphic gaps and/or condensation. The Jurassic formations characteristic of a deep basin (such as Corniola, Rosso Ammonitico and Calcari Diasprigni Fms.) are replaced by Nodular limestones of Bugarone formation above the high structural (Horst).

The subsequent Cretaceous-Paleogene sediments were deposited in a pelagic environment, with fairly homogeneous characteristics. During this time the sedimentation is influenced mainly by climatic changes, which are reflected in variations in color and in the abundance of clay component.

The white-grey debris flows, coming from the adjacent Laziale Abruzzese platform, are peculiar on the Valnerina's geological landscape (Cretaceous-Tertiary time interval).

The Pleistocene continental deposits, surrounding the sedimentary succession described above, are formed mainly by recent floods, detritus and landslide.(fig. 2).

Fig. 2 - Sedimentary succession of Valerina Geological Park.

Reading tips

For a detailed description of the Umbria-Marche sequence, you should refer to classic works of Cashman et al. (1986) and Cresta et al.(1989), or the Italian Geological Society (Passeri, 1994). A local stratigraphic description is contained in the explanatory notes of Spoleto, 1:50,000 scale (Damiani, 2011).

ITINERARY 1 CRETACEOUS ANOXIC LAYERS.

This itinerary (between Roccaporena and Capanne di Roccaporena) allows observing cretaceous anoxic levels: Selli and Bonarelli.

Roccaporena can be reached by Cascia driving along the SR 320 k for about 7 km.

The Selli level (GEOSITE-16a) outcrops at the 1.2 km of the road rising from the center of Roccaporena to Capanne di Roccaporena.

Along the road connecting Roccaporena to Cascia, about 500 m before arriving at Roccaporena, you can observe the Bonarelli level (GEO-16b). We recommend to park in a dirt road between the Corno River and the road. In lean periods, from the square you can get off at the Corno River, where you can see the "Marne a Fucoidi" sequence, with its layers anoxic (black shale).

ROCCAPORENA (geological site; 16 Bonarelli and Selli levels)

In the Valnerina geological park, around Roccaporena, the Selli and Bonarelli levels are visible, exposed respectively to the nucleus and along the eastern flank of a big anticline fold, in N-S direction, parallel to the Corno River (see geological map).

The Selli level outcrops about 1.2 km of the road that connects the village with Capanne di Roccaporena. It is located on the top of the Maiolica formation. It has brown color and thickness about 2 m. (fig. 3).

Along the road Roccaporena - Cascia, you can observe the Bonarelli level. About 500 m before arriving at Roccaporena, covered by rockfall netting, there are rocks belonging to the Scaglia Bianca Fm. towards Cascia, we note a first black cherty level of since one meter of thickness (Fig. 4a). Then the Bonarelli Level (since 1 m. thkns), consists of shales, calcareous clay and yellow and black siltstones. Walking along the road after about 100 m, the Bonarelli Level is visible again to the base of the rockfall mesh (fig. 4b). A doubling of the level, affecting the entire eastern flank of the anticline, is due to the presence of the chevron type's mesoscopic folds.

On the opposite side of the road, in the right bank of the Corno R., the layers of Marne a Fucoidi are visible with its compositional and chromatic variations, folded with spectacular chevron folds (fig. 4 c). Within this sequence, you will recognize several levels of black shales, which correspond to other minor anoxic events

Fig. 3-Capanne di Roccaporena. Selli level at the base of the Marne at Fucoidi and at the top of Maiolica. Red Siltstone, marl and dark levels, rich in organic matter are visible.

Fig. 4-Roccaporena, SR dir 320. A. levels of black chert in the of Scaglia Bianca Formation; B. Level Bonarelli. Alternations of marl (clearer) and clay (darker); C. wall in right bank of Corno River. Chevron folds in “Marne a Fucoidi” are evident in various levels of black shales.

OAES (OCEANIC ANOXIC EVENTS) – GLOBAL ANOXIC EVENTS.

Anoxic events (OAE, Oceanic Anoxic Events) occur when the waters of the oceans established environmental conditions of extreme scarcity or absence of oxygen. This concept was introduced by Schlanger & Jenkins (1976) on the basis of the drilling of the seabed, performed as part of the Deep Sea Drilling Project. The discovery of Cretaceous sediments rich in organic substance ("Black shales") was put in connection with some of coeval marker horizons outcropping in the Apennines, which Selli and Bonarelli levels, indicating the global nature of these anoxic events. Other anoxic events were also recognized in the Jurassic and later Paleozoic successions.

About the anoxic event's studies, the Cretaceous succession is one of the most representative and known in the world, for the presence of important lithostratigrafic markers (Arthur & Premoli Silva, 1982). The "Selli" (corresponding to the event OAE1a) is named after the Italian geologist, Raimondo Selli (1916-1983), is positioned at the base of the Marne at Fucoidi (Albian, lower approximately 120 Ma), and is composed of siltstones and clays/sands with Radiolarian rich in nodules of pyrite and marcasite and/or remnants of fishes (mainly scales and vertebrae).

The second event (OAE2) named Guido Bonarelli (1871-1951), who first described these layers in 1891, outcrops in the area of Gubbio. The "Bonarelli" is located on the top of the Scaglia Bianca Fm. (Cenomanian-Turonian boundary, about 93 Ma) and consists of black Shales, limestones, black and yellow calcareous clay and siltstones with Radiolarians, nodules of pyrite and marcasite.

Many other anoxic events characterize the Umbria-Marche Cretaceous succession, in particular the formation of the “Marne a Fucoidi”, that presents a spectacular rhythm with obvious chromatic variations, with alternation of calcareous and clayey-marly layers or dark layers rich in organic carbon (Parisi, 1994). Calculations on the periodicity of rhythms indicate values that suggest a connection with climatic variations induced by astronomical cycles (Milankovich theory; De Boer, 1982).

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3 TECTONICS

The park reflects the geological evolution of the Umbria-Marche Apennines and comprises three main phases, which led to the current structure (fig. 6).

• Phase 1: deposition of the Umbria-Marche sequence.

From the early Jurassic (Hettangian) to the early Miocene, the deposition of the Umbria-Marche sequence (Fig. 2) took place on the passive continental margin of the paleo-Africa, characterizing by a marine carbonate platform with different depositional environments and thicknesses of formations. In the middle-upper Jurassic, the Extensional Tectonics produced carbonate platform fragmentation, resulting in his drowning and the formation of ups and downs. Subsequently, the continental margin subsidence allowed the deposition of pelagic succession, with features and relatively homogeneous thickness. In the southeastern sector of the chain, the succession is enriched with intercalations flows (limestone), from the coeval laziale - abruzzese carbonate platform.

• Phase 2: Apennine orogenesis. Between the late Miocene and the Pliocene, a compressive tectonic phase has involved the continental margin sequence, leading to the formation major folds with axial trend NNW-SSE, spread by thrust faults and traspressiv faults with NNW-SSE (e.g. fault of Valnerina, fig. 5);

• Phase 3: Recent Extensional Tectonics. The Park, as the entire Umbrian chain, is involved in a constant rising and compressional deformation with NO-SE direction, which cut previous compressive structures and that, led to the formation of fluvial-lacustrine intermountan basins (Norcia, Monteleone di Spoleto, Cascia and Castelluccio di Norcia, Graben of Valcasana basins). The extensional tectonics is still underway with intense and diffuse seismicity, indeed the area was hit in historical times from numerous earthquakes of moderate magnitude (between 5.5 and 6.5).

Fig. 5-Grotti. Valnerina fault

Fig. 6 – Tectonic pattern of the western sector of the geological park.

Reading tips

The tectonics of the area of Coscerno Mt. is described in detail in the work of Barchi & Lemmi (1996), which also contains a geological map of the area, scale 1:25,000.

The thrust of Coscerno Mt. and fault rocks associated with it have been described by many authors. The most recent work is those of Tesei et al. (2013; 2014). The normal fault of Rocchetta is the subject of the work, also specialized Collettini et al. (2014). For a general description of the minor folds in the Umbria-Marche Apennines, refer to classic work by Lavecchia et al. (1983).

ITINERARY 2. FAULT

The itinerary develops on the right side of the Valley of the Tissino River between Usigni and Rocchetta. These two countries can be reached from Borgo Cerreto along the SP 470 of Poggiodomo.

The thrust of Fonte di Colle di Mezzo (GEO-5) is located on the eastern slope of Carpenale Mt. and his best outcrop can be reached from SP 470, for about 1.5 km along a dirt road which starts at the location Immaginetta (Poggiodomo).

The fault of Rocchetta (7 geological site) is located in the northwestern side of Maggio Mt., at 23 km of the road, just before the village of Rocchetta. Other normal faults, well exposed, bord the Graben of Valcasana (GEO-1, Itinerary 4). An interesting Appendix to the route may be the visit to the cave shrine of the Madonna della Stella (GEO-6), an admirable example of continuity, so characteristic of the Valnerina between human presence and natural landscape. In the area of the park there are numerous examples of faults and shear zones developed during its complex tectonic evolution: Jurassic normal fault, faults separating high and low zones; thrust faults and strike-slip faults, referable to the compressive phase of late Miocene; and direct faults generated during the Quaternary extensional phase. This guide describes two significant examples and well differentiated, for tectonic environment and deformation style. The thrust of Font di Colle di Mezzo (GEO-5) is a representative example of fault generated by crustal compression, which is associated with a large cutting area. On the contrary, the fault of Rocchetta is a normal fault extensional (7 geological site), with a crumbly and well localized deformation.

THRUST Fault of Fonte di COLLE DI MEZZO (GEO-5; cutting area with SCC' structures)

Fig. 7-Thrust fault of Coscerno Mt. (Barchi & Lemmi, 1996).

Fig. 8 – Fonte di Colle di Mezzo, Carpenale Mt.. A. Fault rock Outcrop, b. Tettoniti SCC’, c. sigmoidal blocks of limestone in the Scaglia Cinerea (modified by Tesei et al., 2013).

The Anticline of Coscerno Mt. – Aspra Mt. is one of the main structures in the area of compressional Valnerina geological park, developed at the top of a thrust fault of regional importance, which rises to about 25 km N-S direction, immersing the West and a total rejection of several kilometers (see geological map), called Coscerno Mt. thrust. This resulted in the formations the Anticline Coscerno Mt. – Aspra Mt. formations's of the reverse of the inside of the syncline of Mucciafora (fig. 7).

At Fonte Colle di Mezzo is visible on one of the best exposures of the thrust fault (fig. 8a - fig. 8b - fig. 8 c and 9).

The cutting zone is characterized by an intense and pervasive cleavage from pressure- solution, which resulted in the development of "foliage tectonics" (SCC structure, fig. 8 c).

Fig. 9-Tectonics SCC ' in Scaglia Variegate Fm. is visible, with oxidized horizons and well developed foliation.

The FAULT of ROCCHETTA

(geological site 7; mirror of fault with kinematic indicators).

The fault of Rocchetta consists of four major faults, with direction north-south, which extends longitudinally for about 10 km, dipping to the South West and of two antithetical faults, dipping to the Northeast. This set of faults is part of Quaternary fault system, responsible for the region's seismic activity, which includes the faults of Colfiorito-Annifo, Santa Scolastica and Castelluccio.

In here described section is visible a fault dipping in the Southwest (figs. 11 and 12), detaching the Maiolica Fm.(top) by Calcare Massiccio Fm (bed) with an total rejection since 650 m (fig. 10).

The outcrop consists of one long wall more than 40 m high and at least 20 m. At the top of the Calcare Massiccio Fm. is covered by layers of condensed structural succession (Bugarone formation).

The fault of Rocchetta presents a plan with an inclination between 70° and 85° (fig. 13a).

The pattern of grooves and striations highlights oblique slip. This movement has taken place in recent times, during Extensional Tectonics in the Pleistocene. However the fault has reactivated a pre-existing structure, active in the Jurassic, connecting a basin area with a seamount. At the top of the fault outcrop the Calcari Diasprigni Unit, nearTissino River.

Some vertical faults locally interrupt the continuity of the fault plane, by connecting the different segments.

On the right side of the wall, the trace of a low-angle fault (approx. 20°) is present (fig. 12) and it is the wreckage of a Miocene thrust.

Fig. 12-top: overview of studied section. Bottom: line drawing with some potential structures. On the right, you can see the trace of a thrust fault, cut from direct fault.

Fig. 13 - Kinematic indicators on the fault plane of Brochette. A. the fault plane is furrowed by numerous grooves ranging in size from 2 cm to 40 cm, some of which are filled by fault breccia (cataclasite); B. streaks on the fault plane, with variable direction, indicating the variations throughout history-mechanical kinematics; the reddish color of calcite is due to the presence of iron oxides.

ITINERARY 3-FOLDS.

This route allows appreciating one of the most beautiful examples of Valnerina's folds. It starts from Borgo Cerreto. From here you can access to the route of the former railway Spoleto-Norcia (point red in map) towards Piedipaterno. The route of the former railway to discover some great panoramic views on the opposite side (right bank of Nera R.).

Other interesting stops you can do along the SS 685: in particular, at a campsite south of Borgo Cerreto.

The Geological Park area of Valnerina has many spectacular outcrops of folds with tectonic origin. We suggest: the Serravalle area (geological site 15), near Scheggino (GEO-1), along the trail between Usigni and Fonte di Colle di Mezzo (GEO-5) and especially between Piedipaterno and Borgo Cerreto, along the SS 685 and along the route of the former railway Spoleto-Norcia.

EX RAILWAY SPOLETO-NORCIA

The ex-railway Spoleto-Norcia, just south of Borgo Cerreto (km 29.8), crosses the core and the eastern flank of a tight anticline, with roughly N-S direction. In this stretch the Nera Valley narrows between the two galleries Lastra1- 2, the layers of Scaglia Rossa Fm. have frequent intercalations of limestone, involving in a series of spectacular folds. (Fig. 14).

The same folds are also visible on the opposite side of the Valley, along the a-road 209. A particularly impressive outcrop (fig. 15) is visible right across the Lastre 2 Gallery, where a large area shows in three dimensions the morphology of the folds. Just to the left of this spectacular wall, asymmetric folds verging towards east, are present (fig. 16).

Fig. 14-Ex railway Spoleto-Norcia. Scaglia Rossa folds: example of coexistence of different types of lateral folds.

Fig. 15-SS 685, between Piedipaterno and Borgo Cerreto. Cylindrical harmonics folds in Scaglia Bianca Fm.

Fig. 16-SS 685, between Piedipaterno and Borgo Cerreto. Asymmetric folds verging on the East.

4 GEOMORFOLOGY

The Valnerina landforms are due to competition and overlapping of endogenous and exogenous factors.

Among the forms related to endogenous factors (morphostructures), there are anticlines and synclines formed during the compressive tectonic phase (Late Miocene -Lower Pliocene). The anticlines present geometry convex upward with flat crest and flanks steep ("box") and correspond generally at the mountain ridges.

The synclines are very narrow and almost always correspond to the valleys. The geometry of the hydrographic network is strongly influenced by tectonic evolution of Valnerina. The valleys of Nera R. and Tissino R. were originally formed within two narrow synclines. An exception to this geomorphological scheme is valley Corno R., The valley of Corno R. constitutes an example of the inversion relief (Roccaporena, Biselli, Balza Tagliata).

Other morphostructures are related at the Pleistocene raising, following a period of relative stability, during which the erosive action of rivers had generated surface flattened more or less extensive. The raising has isolated and preserved the current drainage system. They are called relict surfaces. A notable example of a relict surface is Avendita Highland (Fig. 17), which grows at an altitude of about 1000 m in the area east of Cascia. The Pliocene-Quaternary tectonics is instead linked the genesis of the basins of Norcia and Castelluccio (see Chapter 6, Quaternary Geology). The morphosculptures, related to exogenous factors, are due to water (river and karst forms) and / or severity.
The forms related to fluvial erosion valleys are: V-trough, flat bottomed, river embankments, river terraces, ditches and / or channels in-depth, high-walled canyons and waterfalls. In the bands of connection between flat parts of the valley and the steep slopes are often present alluvial fans sometimes organized in bands in which they tend to merge (such as in the west side of M. Carrier or in the south west side of M. Coscerno) . The leaching of the slopes determines the forms associated with processes of runoff.

Examples of these phenomena occur in the west side of M. Vettore or in the south west side of M. Coscerno, where there are many channels and grooves. The karst surfaces (dolinas at bowl and with flat bottom) present in the M. Coscerno (e.g.).
An area full of sinkholes is the Pian Grande of Castelluccio, a depression of tectonic origin, whose modeling was completed and enriched by karst processes.
Deep karst phenomena are not common in Valnerina. In the area of Bagni di Triponzo, there is a large hallway or small cavities, including the Cave of Triponzo, discovered during the excavation of a penstock, linked to action of sulphurous waters. The landslides from collapse, sliding, debris flows, landslides complex (fall-slip), deep-seated gravitational slope deformations (DGPV) and morph types associated as trenches, slopes and split crest. are present in the Valcasana area.

Fig. 17 - Plateau Avendita (view from the Maggio Mountain).

Reading Tips

A comprehensive discussion of the morphological features of this region can be found in the monograph of the Gentili (2002). For a more referred to the territory of the Park, still we refer to the notes to the Foglio Spoleto (Damiani , 2011). The gravitational phenomena of the area of Coscerno Mt. are the subject of the works of Cardinali et al. (1989) and Barchi et al. (1993). Mattioli & Terzigni (2008) describes the flood along the Valcasana. The debris flows Valnerina have been the subject of recent studies by Reichenbach et al. (2004), Conversini et al. (2005) and Salciarini et al. (2006).

ITINERARY 4 Geomorphology Structural

The Valcasana (geosite 1) is passable for about 8 km from Scheggino to Gavelli through the CAI 8 "Strada delle Ferriere". Along the SP 471, which connects Sant'Anatolia di Narco to Gavelli, you can go down to the Pian Melette (Geosite 2) from Caso (easy and short hike of 1.2 km of gravel road with descent of 85 m) and then back along the average Valcasana, which represents the most significant part of the itinerary. Gavelli can be reached from the summit of Mount Coscerno (Geosite 4). Go before the carriage road after about 3 km leads to the Forca di Legno (1236 m), then turn left and drive about 800 m a trail to the fork of the Spina (1274 m). Across the fence, reach the path n. 30 CAI uphill for about 4 km (with a vertical drop of 350 m). This climb is quite strenuous for the altitude, rocky terrain and overly sunny.

The Valcasana is a graben stretched for about 11 km towards NW - SE, whose morphological expression is a narrow and deep depression that interrupts with great evidence the longitudinal continuity (see geological map) dell'anticlinale Coscerno Mt. The genesis of the valley is related to extensional tectonics Pleistocene, which has displaced the fold structures, formed during the previous compressive tectonic phase (Miocene).

The correspondence between the structure and morphology is particularly evident. The peaks of Coscerno M. and Civitella M. are respectively at an altitude of 1684 m 1565 m above sea level, while the bottom of the small basin of Pian Melette is at an altitude of 579 m above sea level. The difference in altitude of about 1000 m corresponds almost perfectly to maximum rejection of faults. This height difference is made all the more striking by the reduced transverse dimension of the structure , whose main fault lines are located on average about 1500 m.

The steep slopes of Valcasana between Coscerno M. and Civitella M., are affected by complex gravitational phenomena, as slopes, landslides from collapse, landslides, debris flows, landslides complex (fall - slip), deformation deep-seated gravitational slope (DGPV). The beginning and the evolution of these phenomena are often controlled by structural factors, sometimes inherited from the Miocene - Pliocene compressional deformation, sometimes generated by successive dislocations relaxing (Pliocene - Quaternary). It is obvious relationships between slope movements and tectonic phenomena. The presence of varied and representative phenomena of instability make this area an ideal training ground for those who want to become familiar with the topic of the relationship between tectonic and morphological evolution of the slopes.

The slopes of the Valcasana have gradients that reach even 80%, and have a complex profile (rectilinear interspersed with convex-concave portions). They are characterized largely by predominantly limestone rock walls, stripped naked and subjected to constant degradation phenomena that cause physical detachment and accumulation at the foot of debris.
In the following, after the description of the tectonic structure of Valcasana, we focus on two phenomena representative of the complexity and peculiarities of this valley. The first is a large rock fall, which affected the north-eastern slope of Mount Civitella, causing the damming of Fosso Della Valcasana. The second is a gravity deformation deep slope (DGPV) that affects the south west side of M. Coscerno, involving a hundreds of millions of cubic meters.

THE GRABEN OF VALCASANA (geosite 1)

The geometry of the graben Valcasana is complex and includes, in addition to major faults, numerous minor synthetic and antithetic structures (splays) (Fig. 18). The deepest part of the graben is central, between Caso and Gavelli where fault lines reach maximum rejection (sections B-B 'and C-C' of Fig. 18); moving away from this area, the rejection tends to decrease quickly (sections A-A 'and D-D' of Fig. 19). The SE Gavelli morphology associated with the structure is much less pronounced: the sunken part of the graben corresponds to a plateau with widespread karst surface (Laghetto di Gavelli) and small reservoirs, with colluvial deposits, marsh and concretions containing ferrous (iron of swamps; Damiani, 2011). The southwestern border fault is clearly visible on the valley floor by the trail number 8 of the CAI.

Fig. 18 - Geological sections through the Valcasana Graben (modified from Barchi & Lemmi, 1996).

Fig. 19 – Normal fault on the slopes of M. Civitella, where it is evident that the plan makes contact Majolica (right) and Calcare Massiccio (left). B. Plan fault located on the slope of Coscerno Mount, along the SP 471 that connects to Gavelli case.

In the north-eastern Civitella M. is evident the tectonic contact between the Maiolica and the Calcare Massiccio, with a rejection of over 400 m vertical (Fig. 19a). In this area the morphology of the slope, which is constituted by a series of faults dipping NE, is closely linked to that of the border fault. Along the SP 471, between Caso and Gavelli, there are some minor normal faults, which border the south west side of M. Coscerno. One of these is well exposed (Fig. 19b) just before the village of Gavelli.

PIAN delle Melette (geosite 2; landslides and dammed lake)

The Pian delle Melette is a flat area of about 12 hectares, located at the mouth of the average Valcasana. The site is limited to the west by an escarpment (Fig. 20a). The Pian Melette was formed in the Pleistocene-Holocene, following the formation and the subsequent filling of a dammed lake. Fosso Gavelli was barred by the collapse and sliding of about 3 million cubic meters of rock material (mainly derived from the layers of Majolica) collapsed from the north-eastern Civitella Mt. (Fig. 20b).
The gap was caused by the intense billing area hinge Western dell'anticlinale M. Coscerno, on the western slope of Mount Civitella (Fig. 21a). The dam in the valley caused the formation of a small lake, which was gradually filled by sediments of lakes, marshes and rivers mostly fine (silt, clay and peat). Pian Melette is precisely the result of the replenishment of the dammed lake. The southeastern edge of the plain is gradually invaded by debris transported from Fosso Gavelli during flooding, which form an alluvial fan, which is connected to the flat area.

Fig. 20 - A. Pian Melette: the landslide that generated it and the detachment; B. Boulders Maiolica metric sizes, belonging to the body of the landslide that generated the dammed lake.

From the village of Case there is an excellent panoramic view site: in particular, you can see the strong morphological contrast between Pian delle Melette and the steep slope of the Civitella Mt., which corresponds to a natural section of the western flank dell'anticlinale M. Coscerno (Fig. 21a). Fig. 21 - A structural diagram of the north-eastern M. Civitella. You can see the structure anticline and the net displacement by either high-angle reverse fault; B. palaeo-landslid Pian Melette. They are highlighted in red the detachment niche and the area of sliding, in yellow the accumulation of landslide, while the white arrows indicate the direction of movement

The splitted crest of the Coscerno Mt.
(Geosite 4; gravity deformation deep slope)

The south west side of Coscerno Mt. is subject to a gravity deformation of deep (DGPV) involving an estimated volume in 300 to 450 million m3. Along this front, the main factors, which favor the formation a DGPV, are present:
high energy, triggered and maintained by tectonic uplift region; consequent deepening of the graben Valcasana and the increase in the slope; lack of lateral support; presence of rocky material; presence of a water course in erosion. All these factors have increased the tensions and instability, favoring this particular type of deformation.
The peculiar morphology top of Coscerno Mount, which has two ridges aligned and parallel, separated from a lowered area, it is one of the main evidence morphological DGPV (Figs. 22 and 23a). The phenomenon the doubling of the ridge affects the portion central southwestern slope of Mt. Coscerno, for a total length of about 2.5 km. (Fig. 22).
The splitting of the crest develops SE of a clear trench (Fig. 23b), over 20 m high at an altitude of 1600 m above sea level, at the Fosso del Miracle.

Fig. 22 - Evidence of morphological DGPV: doubling ridge (in orange), the trenches and the longitudinal cross (in red) and the convexity of the radial side (in yellow).
Fig. 23 - Ridge Coscerno Mt. A. View towards SE: splitting clear the ridge; B. Trench, delimiting the phenomenon of splitting NW.

Strains Gravitational SLOPE OF DEEP - DGPV

The deformations gravitational deep Versante (DGPV) are movements of large mass, which take place for creep deep with plastic deformation, differential and spatially continuous, slow and progressive, with a speed of a few mm year. A DGPV does not necessarily produce a well-defined cutting surface but usually together more surfaces of deformation variously oriented (Savage & Varnes, 1987; Chigira, 1992). The ranges of dimensions are of the order of several kilometers while the depth is tens or hundreds of meters. The movements are relatively small compared to the side.

There are two types of DGPV: sackung and lateral expansions. The sackung produce associations of shapes attributable to efforts lazing in the upper part of the slope and compression in the basal part.

Along the top of the hills and through the upper middle produces double ridge, trenches, carvings, counter-slopes, escarpments; while at the base the compressive stress results in an increase of superficial landslides. The coherent, fractured or laminate, rock types are involved on the viscoplastic deformation in depth. The lateral expansions differ in the orientation of efforts subhorizontal extensional and can trigger both along the ridges chain litho logical particular conformations.

In Italy, most of the phenomena are present in the western Alps and in the Central and Central and South America, for the simultaneous presence of favorable structural factors (Dramis & Smile-Valvo, 1994), such as the presence of a substrate consistent, high relief, a drainage network characterized by strong linear erosion and earthquakes with high values of magnitude.

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ITINERARY 5. THE DEBRIS FLOWS

This itinerary allows you to see two examples of debris flows, a very common phenomenon in Valnerina.

The debris flow Gavelli (Geosite 3) you can visit the area storage (accessible by the trail the CAI 8) and the beginning (accessible by trail to Gavelli to reach the summit of Civitella Mt.). The area of transport, as well as that of ignition, they are partly visible in the view from the SP 471, just before reaching the village of Gavelli.

The sites of debris flow are: Piedi Paterno and Grotti (geosites 8 and 9). They can be reached by taking the SS 685. It should turn in the junction for Piedi Paterno, Grotti and Meggiano and take the SR 395 (Passo di Cerro). For the site of Piedi Paterno one stops after less than 500 m in correspondence up area, while for the site of Grotti must turn right after about 5.2 km and head towards the town.

Phenomena of debris flow are very frequent in this area and take place along the watersheds that cross steep slopes, such as the Valcasana (debris flow Gavelli) or at the edge of Avendita (debris flow of San Giorgio). Other examples are those that occurred in the right bank of Nera R., in correspondence with the countries of Grotti and Piedipaterno.

THE DEBRIS FLOW OF GAVELLI (geosite 3, area of separation and storage)

On the night of April 18 of 1999 a considerable amount of debris it came off suddenly along the NE side of Civitella Mt., near an incision in the west of Mount Rotondo. The noise caused by detachment and by the sliding mass of debris was strong enough to wake residents Gavelli, who warned the relevant departments. The outcrop along the side of the Marne a Fucoidi, training mechanically weak and not very permeable, He has certainly played an important role for localization of instability, causing the formation of the incision, produciding a debris characterized by considerable speed and energy: in a few minutes, the debris flow carried along the side, depositing it at the foot of slope, along the valley of Valcasana (Figs. 24a and 24b). Currently the signs of instability are partly deleted by time and by human activity. The part of the site reached by the CAI path n. 8 is represented by deposit into the valley, where they are visible signs mechanical smoothing of the terrain. Along the side, just beyond the hermitage of San Antonio, the detachment landslide zone has stopped the path from the source of Scentelle, near the Gavelli Lake, allows access to the summit of Mount of Civitella. In this Regional points realize how the debris flow have affected area subject to repeated phenomena this type, whose evidence is well recorded in the landscape (presence of niches, escarpments and counterslopes).

Fig. 24 - The debris flow Gavelli. A. Aerial view of the area of separation and accumulation; B. Accumulation of material on the valley floor the morning after the event (courtesy of A. Sorrentino, Umbria Region).

THE DEBRIS FLOW OF PIEDIPATERNO AND GROTTI
(Geosites 8 and 9; historical memory and works of prevention)

At the mouth of the river Lagarelle, at the country of Piedipaterno, two other imported debris flow events in 1945 and 1965 occurred. The creek burns on the south east of the Galenne Mt. at an altitude of 1.060 m. and flows into the Nera River to 313 m above sea level. Its basin covers about 2.4 km2 and is located on the right bank of Nera River. The creek is characterized by widespread subsurface flow, favorite the high permeability of the bed that you set for much of its path on limestone rocks. An outflow concentrated in the channel it occurs only in the case of severe thunderstorms or rapid snowmelt. In the upper part of the basin, the units of the series Umbria-Marche outcrop: the overlap limestone formations, strongly fractured and permeable (Scaglia Bianca and Rossa) with major component marl, less permeable (Scaglia Variegata and Scaglia Cinerea) has certainly favored the development of the phenomenon. Recent alluvial deposits landslides of varying thickness covering the bedrock. Slopes greater than 25 ° characterize the morphology General of the upper part of the basin, while the lower part with gradients most sweet, with average values of about 17 °, with the exception of local situations in correspondence of embankments of landslide, where the slope increase significantly. An element morphological pronounced is the alluvial fan located at the mouth of the river basin Lagarelle, where it developed the building's recent country Piedipaterno (Fig. 25).

Fig. 25 - Panoramic view of Piedipaterno. The village is built on an alluvial fan fed by events of debris flow at the mouth of the river Lagarelle.

On 6 September 1945 a heavy rain triggered a rapid movement of debris; a first wave arrived in full town, dragging large blocks of rock with size up to 3 m3. The mixture of water and sediments crossed the village and reached the Nera River, followed quickly other four waves. The accumulation of sediment has obstructed the section of the river, at the bridge connecting the two banks. The water flooded the first zone upstream of the dam and then, after the river had eroded the body debris, spread in the downstream area, severely damaging the country and infrastructure.

A second important event took place in same area September 2th, 1965: in this case the most rock blocks, transported by the debris, stopped at the country, damaging many buildings. Following the event were built upstream of Piedipaterno bridle containment to prevent further damage.

In September 1965, a debris flow event occurred Baroncelli at the mouth of the river, near the village of Grotti. The stream born on the southern of Galenne Mt., at an altitude of 1000 m.

In September of that year, after a strong storm, they are activated by multiple shallow landslides scarps and the eroded region, evolved rapidly in debris flows channeled along the watershed. The debris reached the village of Grotti, destroying and flooding partially houses in the top of the cone on which stands the town today. (Fig. 26).

Fig. 26 - Torrente Baroncelli, Grotti: historical photos of the event September 1th, 1965 (by Salciarini et al., 2005).

After the event in 1965, nine dams were built c (Fig. 27). Although after 1965 are not recorded other debris flow events, aerial photos of 1977 show the reins full of debris.
The events of Grotti and Piedipaterno have been widely studied in recent years, in order to develop the methods of prediction / prevention and to determine the level of risk associated with them. These studies have confirmed that the frequent debris flows are in these watersheds (3 events in less than 50 years old).

Fig. 27 - The dams built along the Baroncelli River, upstream of Grotti.

The debris flows

The debris flow (debris flow) is a natural phenomenon that occurs along the incisions of mountain basins with high slope and looks like a wave of debris (sediment, logs, shrubs, etc.) Mixed with water; It has a very steep front (comparable to a "wall" of debris), and extends with a sudden flow, traveling at high speed and with high destructive power. The debris flows are particularly dangerous for their high speed, their destructive impact and are difficult to predict.
The density of the material that constitutes a debris flow is similar to that of a casting of volcanic lava (1, 8-2, 0 g / cm3), with a particle size which varies from clay to blocks of several m3. The average speed is 3-4 m / s and a maximum of 20 m / s, the duration of the phenomenon varies from a few minutes every hour, while the volume from a few hundred to millions of m3.
A debris flow is distinguished from a normal stream in full for the solid contents and the fact that the water (about 80%) and solid particles (about 20%) move at the same speed, as a single body. To enable a stream of debris requires at least three conditions: 1. the presence of debris promptly mobilized; 2. steepness of the engraving between 15 ° and 40 °; 3. intake of a sufficient amount of water.
Water can come from: short and intense rainfall (summer storms), precipitation of long duration and low intensity, rapid melting of snow fields or glaciers, loss of water bodies trapped in glaciers and karst caves. The material mobilized at high speed, form one or more waves (similar to the dynamics of lava flows). The movement has intermittent: recognizes a series of arrests or decreases the speed along the path to the decrease in slope, curvature of the streams or the formation of temporary barriers that block the flow of the river temporarily. The flow of debris has, from upstream to downstream, a zone of a beginning, transport and storage. In the beginning (1) prevails erosion, while in the area of transport (2) Erosion is equal to the deposit (3). There are rocky surfaces clean, trace of mud or impact signs of coarse material on the surface of trees, buildings, etc. The incision has a characteristic section of an approximately trapezoidal. The materials smaller are arranged downwards, while at the top are the most abundant larger blocks. In the storage area, the exit of mountain streams, alluvial fans are finally present with frontal lobes that have contact with the bottom of the valley. The vegetation has a dual effect: low speed (cone) may slow down to the trees, divert or stop the movement; where the speed is high (long incision) trees can be uprooted and carried, by increasing the mass in motion, or they can create "dams".

JOHNSON A. M. & RODINE J. R. (1984) - Debris flow. Slope instability, 257-361.

ITINERARY 6: GORGES AND WATERFALLS

The itinerary, which grows mainly along the Corno Valley, allows observing two of the deep gorges carved out by it (the Stretta di Biselli, geosite 15 and Balza Tagliata, 14 geological sites). The waterfall example proposed is "Lu Cugnuntu" (geosite -12).

To observe the Stretta di Biselli take the SS 685 from Serravalle to Biselli, park in a small clearing on the right near the Biselli 1, cross the street and walk about 200 m of its old route.

The Balza Tagliata is achievable from Triponzo about 2 km the old highway to Norcia, now closed to traffic following the collapses that occurred during the earthquake of 1997-98.

The cascade of "Lu Cugnuntu" is accessible from the village of San Lazzaro, located along SR 209 a few kilometers after climbing about Belforte.

The genesis of the Gorges is linked to the deepening of the hydrographic network during the raising chain, took place in the Pleistocene and still going on with a speed of about half an mm per year. The many small waterfalls of Valnerina were formed at morphological jumps, the presence of faults (Hermitage of the Madonna della Stella) or less erodible layers (waterfall of "Lu Cugnuntu", linked to calcarenitic levels interspersed in the Scaglia Rossa).

The narrow gorges, carved in limestone, often difficult to cross, are often a connection with larger valleys, have always influenced the development of the road network in the area. The itinerary includes some significant examples.

STRETTA DI BISELLI

(geological site 15; Gorge by Corno River in limestone of Maiolica)

Between Serravalle and Biselli, the Corno River flows from East to West, across a major anticline, with North-South: these deep natural sections allow you to fully appreciate the stratigraphy and tectonic evolution of the chain.

The core of the Anticline, with Disprigni Limestone, is exposed at the town of Serravalle, the confluence with the river. Proceeding westward, after several large sub walls-tiled vertical, the Valley narrows abruptly, giving rise to "Stretta di Biselli", a spectacular example of the Gorge inside a mountain ridge. The Gorge features vertical walls, about 50 m from the River, carved in the limestone layers of Maiolica, dipping to the West, where you can also view beautiful examples of folds with Western vergence.

BALZA TAGLIATA (geological site 14)

Corno River has carved a deep canyon into the Limestone of the core Anticline. At the narrowest point of the Gorge is the site of Balza Tagliata, a section where a Calcare Massiccio outcrop with a thickness of more than 700 m. above this is a Jurassic succession high condensed, nodular limestone consisting of Bugarone group, which passes upwards to Diasprigni Limestones and Maiolica.

West limestone Massif is put in direct contact with these deep limestones from an important high angle fault. This fault has influenced the development of the Corno River in this stretch, as well as other tectonic lines have done in other traits.
The site also has a considerable historical interest due to the presence of a wallray (sliced), pre-Roman, carved into the rock wall on the right bank of the Horn, the only road connecting the Valley to reach Norcia.

Fig. 29-Balza Tagliata: the ancient roadway (pre-Roman) is carved in natural Solid limestone wall.

CASCATA DE "LU CUGNUNTU"
(geological site 12; waterfall and gorge carved into the limestone Scaglia Rossa)
The waterfall, 20 meters high, is located at the end of a blind gorge excavated in Scaglia Rossa Fm.
The layers dip into IT and have a high inclination (about 70°), with some nice folds, chevron, related to tectonic compression phase.
The waterfall is located along a stretch of the Valley, probably has developed to the presence in the upstream of rock resistant to erosion (very common in Scaglia Rossa Fm.).
Head ward erosion of the waterfall due to the uplift of the relief and the resulting imbalance of the watercourse, has instead created the Gorge.

Fig. 30-Cascade de "Lu Cugnuntu".

5 QUATERNARY GEOLOGY

The recent evolution of the territory of Valnerina is particularly complex and its rapid evolution has produced a set of forms and deposits of great interest. In this great richness and variety of phenomena, we chose to study two particularly significant and spectacular aspects of the Quaternary Geology: the plans of Castelluccio, representing one of the most relevant examples, even from the point of view of landscape, basins of the Apennines; and travertine deposits, which are the result of the complex interaction between tectonics, climate and circulation of fluids underground.
One of the peculiarities of the Apennines, which occurs constantly from Lunigiana to the Calabria, is the presence of recent basins flat-bottomed, bordered by faults, constituting a singularity than the succession of valleys and ridges, which are described in the literature as "intermontane basins".
These tectonic depressions are closely related to recent and active tectonics, as demonstrated by the close connection, already noted by lots (1926), between the distribution of conches and those of historical earthquakes, which are often known as the dock itself, as in the case of the Garfagnana (1920), Mugello (1919), Fucino (1915) and Val d' Agri (1857), just to mention some examples.
In Umbria, basins are those of Gubbio, Colfiorito and Annifo and, in southeastern Umbria, Norcia, Cascia (plain of Santa Scolastica, fig. 31) and the plans of Castelluccio (fig. 32).
Travertines are widespread in Central Italy and many outcrops are well-known since antiquity, because this rock, durable and well worked, was widely used as a building material.
The Valnerina is rich with travertine deposits, such as in the areas of Triponzo, Sellano and Preci (fig. 33).

Fig. 31-Santa Scolastica plain: panoramic view of Norcia.

Fig. 32-great plain of Castelluccio

Fig. 33-Abbey of Sant'Eutizio. The travertine rock on which is built the Abbey complex.

Reading tips

Castelluccio, plus a great importance from the point of view of nature and history (Charles & Lollini, 1988), is subject to extensive geological literature.
The stratigraphy can be found in the Ge.Mi.Na volume. (1962). Lippi Boncampi (1963) has conducted investigations and the hydrogeological basin and Quaternary evolution of faults that control it are the subject of work by Coltorti & Fairweather, (1995) and Calamita et al. (1993). Galadini & Galli (2002) have dug trenches through the paleoseismological bordiere faults, which were subsequently investigated by Ebenezar et al. (2014) using geophysical methods. Regarding travertine to Triponzo, the works by Fairfield et al. (2005) and Ferrera et al. (2013) are included.

ITINERARY 7 CASTELLUCCIO

The three floors are easily accessible by road.

From Norcia (hence Castelluccio is 30 km) through SS and SP 685 477, Visso (hence Castelluccio is 21 km) through the SP 134. The tops are cut by a series of streets and easy trails, where motorized traffic is prohibited.

Of particular interest in Pian Grande (GEO-18a) is the Sinkhole, accessible from SP 477 through CAI 556 (approximately 1.5 km).

A good view of the Pian Perduto (geological site 18b) is from the village of Castelluccio, from the paved road that runs along the northern side of the relief on which it stands.

The Pian Piccolo (Geological Site 18 c) is the path CAI 557, which connects Forca di Presta in Cese.

In the southeastern sector of the Umbria-Marche Apennines, the chain of the Sibillini Mountains, formed in late Miocene-Pliocene, during compressive tectonics, was later covered by Pleistocene Extensional Tectonics (see geological map). More extensional structures in the area are aligned along the two fault systems managed with NNW-SSE direction, which have been the subject of numerous studies of structural geology and seismotectonics: Norcia-FEMA Mt, whose roof comprises the basin of Norcia (plain of Santa Scolastica); and the system of Vector Mt. -Bove Mt., which is linked to the formation of the Castelluccio plain.

The system of Vector Mt - Bove Mt. is formed by a set of faults, arranged en-echelon, dipping to WSW, connected by minor faults.

The plans of Castelluccio constitute a system of intramontani basin, surrounded by an unbroken circle of mountains, which have shares of 1600-1800 m s.l. Northern sectors, west and south and 2000-2500 m s.l., in the eastern sector (Vettore Mt. and Argentella Mt.). The Floors are divided into three enclosed basins, flat-bottom: Pian Grande, which is overlooked by the village of Castelluccio and the impressive South-western slope of the Vettore Mt.; Pian Perduto, immediately N of Castelluccio, along the road leading to Visso and Pian Piccolo, where the large floor and separated from this by Guaidone Mt.. The northernmost of the Pian Perduto is oriented in N-S direction, while the other two are from N-and S-W, almost perpendicular to the Western side of the Vettore Mt.

PIAN GRANDE (GEO-18a)

At the pass between Ventosola Mt. and Ca Mt., you can overlook the great plain of Castelluccio and enjoy remarkable views, including the village of Castelluccio and the Western side of the carrier (fig. 34).

The great plain has an area of 13.09 km2 and is elongated in the direction of NE-SW. The distance from the northernmost point (Collacci) and the South (on the floor, behind Costa Sassetti) is about 7 km. The width varies between 1.75 km and 3.1 km. The maximum altitude (above Source delle Monache) is 1330 m s.l.m., while the minimum (1257 m l.m.) is at the Sinkhole of Mergani on the Southeast edge of the basin.

Fig. 34-panoramic view of Castelluccio. The red lines represent the trace of the main faults with NW-SE direction.

From tectonic point of view, the great plain is an asymmetrical graben: on the eastern edge of the basin is controlled by a staircase of faults, to dipping WSW, the most important of which (fig. 34) runs at the base of the South-Western side of the carrier, on the northeastern edge of the floor. This fault has a rejection maximum of about 1200 m.
The easternmost structure, known as "Cordone del Vettore" (fig. 34), is located a few hundred metres below the crest and view a rejection of 250-300 m.
A series of trenches dug by geologist along the foothills of Vettore Mt. has revealed the presence of a fault that displaces Holocene deposits, allowing a possible earthquake occurred in prehistoric times (around 3000 years ago). Because of these characteristics, some authors define the fault as a silent structure. The geometry of the fault has been further investigated, using techniques of sub-surface geophysical (Ground Penetration Radar).
On the low block, the roof of the faults, a basin developed, which was filled by colluvial deposits and Lakes/marshes. In the years ' 60, during prospecting campaigns, five wells were drilled, the deepest of which, near la Rotonda, met the substrate to a depth of approximately 100 STS geo-electric prospecting and have estimated that the maximum thickness of the deposits can reach 400-500 m in the northern sector.
The replenishment of Pian Grande consists of alternating layers of silty-clay soils, associated with lacustrine or marsh episodes, and gravel layers of fluvial-torrential origin (alluvial fans). Such deposits are placed chronologically between the Pleistocene and the Holocene.

In the Pian Grande, the alluvial fans coalescents are present (fig. 35) consisting of medium-coarse clasts. The corresponding forms of erosion, along the slope, are represented by single ditches, erosion along the side (fig. 35).
With the help of photo-interpretation, it is possible to recognize evidence plan of morphogenesis. There are such ancient palaeo-river beds, fans and sedimentary bodies, hardly recognizable in the country.
Although the origin of the plans of Castelluccio is predominantly tectonics, the karst has accompanied and influenced evolution. The great plain is an example of centripetal drainage basin, lacks a visible emissary to the surface. The underlying basin plans of Castelluccio receive on average an amount of water almost 70 million m3 per year. Water drainage takes place by the main underground of absorption occur superficially with dolines and Sinkholes, the most obvious of which is that in which it meets the Fosso dei Mèrgani, on the southern edge of the great plain (fig. 36).

Fig. 35-Runoff processes and alluvial fans on the South West side.

Fig. 36-Great plain of Castelluccio: Fosso dei Mèrgani.

The main absorption of the water occur superficially with dolines and sinkholes, the most obvious of which is that in which it meets the Fosso dei Mèrgani, on the southern edge of the great plain (fig. 36).

In the spring of 1947, 1963 and 1966, Lippi Boncambi introduced increasing amounts of fluorescein (1, 10 and 50 kg) into the Sinkhole to establish some kind of relationship with the underlying hydrologic system, which flow on both sides of the Sibillini Mountains. Colorimetric tests were unsuccessful, so still we don't know where and how quickly the waters it absorbed by sinkhole to escape on the surface. Evidently the karstic process has not yet had the time to make quick scrolling culverts resurgence underground.
The contribution of the karstic process modeling of Pian Grande is highlighted by the large number of sinkholes, spread all over the floor, particularly in its southern portion, where the waters converge in sinkhole.

The Sinkhole, at an elevation of 1257 m., is a funnel-shaped structure that closes the ditch; the fund, irregularly shaped and situated 20 m below the level of the floor, has a maximum width of about 25 m and wide cracks several decimeters, the calcareous layers of Calcare Massiccio. Speleological surveys began in 1981 highlighted large and deep fractures on the bottom of the sinkhole (fig. 37).

Fig. 37-Pian Grande: aerial view of the sinkhole. A. view from the northern edge of the Fosso dei Mèrgani. The yellow arrow indicates the location. B. detail of the entrance of the sinkhole, which shows the lack of protection of the site.

PIAN PERDUTO (geological site 18b) The Pian Perduto is famous for the eponymous 1522 battle between the armies of Visso and Norcia, which was won by Van JAARSVELD and that brought about the end of the age-old contention for his property. Pian Perduto has an average altitude at 1335 m, N-S length of 1.5 km, a width, and-W of 1.2 km and an area of 2.39 km2. It is connected to the West with Cànatra Valley, on the North by Valle San Lorenzo, to the South by the Pian Grande, from which it is divided from the Hill of Castelluccio.
Pian Perduto has a karst with irregular branches; the water is detectable by patches of intensely verdant grass.

Fig. 38-Pian Perduto: panoramic view from Castelluccio.

Pian Piccolo (Geosite-18 c)

The Pian Piccolo has a NE-SW direction. The highest point (1350 m) lies to the South under the Fonte del Vescovo, while the lowest (1300 m) lies to the North of the Bonanno Valley. Its length is 5.5 km, its width is between 200 and 800 m and its area is 2.34 km2 (fig. 46).
The highest part of the basin (1335 m, Southwest, under Cappelletta Mt.) is a catchment area and drainage, the latter ends in the pond about 150 m wide. In it there is an insect endemic (found only in this place), Paraleptophlebia ruffoli. Around the pond is relatively easy to observe the thick layer of peat, which reaches one meter thick.

Fig. 39-Pian Piccolo: view towards NE; in the background is visible on the Vettore Mt.
Fig. 40-Pian Piccolo: panoramic view of W.

ITINERARY 8 THE TRAVERTINES

The route is divided into two distinct areas, one near Triponzo (right) and another at Sellano (Fosso delle Rote, left).

Triponzo is located along SR 209 Valnerina between 48 and 49 km. Near the Grotta del Lago, interesting concretions are visible, is reached along the trail to Triponzo in Bagni di Triponzo (Benedictine Trail 501 and Trail 9A of the Greenway of the Nera R.). Balza Tagliata is easily accessible from Triponzo. Across the SR 209, turn right and walk for about 500 m until the barrier that stops the old highway to Norcia. Proceed on foot for another 1.2 km, along the same road, closed for the collapses that occurred with the earthquake of 1997-98.

To reach Sellano the Fosso delle Rote, take the SR 319 towards Foligno for 200 m, then turn right (signposted the “Cascata delle Rote”) and take a road paved and dirt before then. Descend into the Valley of Vigi River and continue up to the point where it crosses the River (2.3 km from the junction).

Park the car in a clearing on the left before a jumper on the Vigi (CAI signage) and walk. Across the River, you fall on the dirt road, and then, after few meters, turn right on a path/trail (n. 586), where there is a wooden sign with Setri - Peneggi.

Geological Park of the Nera Valley, in particular, has significant examples of travertine deposits (like "calcareous tufa") and fossils (like Triponzo, Balza Tagliata and Postignano).

THE TRAVERTINES OF TRIPONZO

(geological site 10; fluvial deposits and microbial; Lake Dam)

The village of Triponzo stands on a travertine bench, extended on both sides of the Valley, at the confluence of the Nera River with Corno R. (fig. 41): the rocky body extends for about half a square kilometer and reaches a maximum thickness of almost 90 m.

The tour consists of two separate deposits, formed at different times and currently arranged at different heights. The first phase of deposits date back to the late Pleistocene (46000 ± 5000 years ago) and extends above the village of Triponzo, reaching a maximum altitude of 450 m above sea level. Deposits of the second phase of the Holocene and featuring various episodes of deposition and erosion between 8240 ± 75 years ago and 2825 ± 60 years ago are closer to the current base of the Valley, reaching a maximum elevation of 420 m.

The oldest storage reaches a maximum thickness of about 60 m, on the left bank of the Nera River, opposite the village of Triponzo. These travertines (or "calcareous tufa") are mainly composed of “fitoermal facies” and are characterized by a low porosity for the strong presence of secondary calcite, deposed by the circulating waters inside the rock. Latest deposits are mostly composed of alternating sands and gravels with few meters thick of travertine (Fig. 42).

Fig. 41 - The travertine visible at the confluence between the Corno and Nera Rivers.

Fig. 42 -Triponzo, Grotta del Lago: travertinose concretions, probably microbial structures underwater.

The TRAVERTINE Di BALZA TAGLIATA

(geological site 14; fluvial deposits)

Travertines of Triponzo stretch along the Valley of the Corno River, up to the throat of Balza Tagliata. Some outcrops, correlated with those Pleistocene cycle, are easily accessible along the old route of SS 320, closed due to landslides occurred as a result of the earthquakes of 1997-98. These were probably deposited travertine in the riverine environment by rapids and waterfalls (fig. 43).

At one kilometre from Triponzo is well exposed the support of continental deposits, nonconformity vertical layers of tiles (fig. 44a): the surface of discrepancy occurs; among the Mesozoic limestones and travertines are pockets of fluvial conglomerates, with well rounded limestone clasts, which testify to the travertine deposition in a fluvial environment. In places, little Leaps above the remains of the ancient roads, excavated in the rock, which gives its name to the site, the vertical wall of limestone Massif is covered by strips of travertine blocks, suspended some tens of meters than the current bed of Corno (Fig. 44b).

The travertine of Balza Tagliata and Triponzo are Cut to the roof of a major high angle fault (see route 6), which skirts the West Anticline of Acuto Mt... Throughout the Apennine region, the genesis of travertine and of calcareous tufa is often linked to the presence of faults: the Sant' Andrea fault in this case, by lowering the block of West Triponzo, may have created a morphological step, on which it established a waterfall environment. The fault also may have favored the return of deep waters rich in calcium carbonate. It should be noted in this regard that the continuation of the fault to the North there is the thermal spring of Triponzo (geological site 11, route 9).

Fig. 43-Triponzo, ex SS 320. A. Algae encrusted, indicating a current direction from right to left (from S to N) consistent with the current level of Corno river; B. waterfall deposits. Also in this case the flow was from right to left (N) (S)

Fig. 44-a. Triponzo, ex SS 320: travertine in on nonconformity verticalized of Maiolica; B. The travertine is suspended over the river bed.

FOSSO DELLE ROTE

(geological site 13) his course of the Fosso di Rote, located in a hanging valley of the Vigi river, is characterised by several morphological jumps with Rapids and waterfalls, where the precipitation of travertine deposits is still active.

In the upper part of the water flows plentiful and forms a series of rapids at small jumps with morphological overlap with fitoermal deposits and tubs. The growth of barrages, due to continuous deposition of travertine, influences the water flow up to divert the flow (fig. 45). In the most upstream there are Rapids and waterfalls; the latest is ten metres high. On the side of the latter, along the trail, there is a high cliff of fitoermal travertine (fig. 46)

Going back towards the Vigi River, some big jumps (with more than 50 m altitude) are present. At the base of the last jump there is a small cavity, a fine example of giant exhaust, typical landforms of the falls due to the erosive ability of waters, here with particularly turbulent conditions (Fig. 46b).

Fig. 45-Travertine Barrier at the top of the Fosso delle Rote.

Fig. 46-a. Travertine on the top of the Fosso delle Rote valley; B. The Rote waterfall (currently dry) with underlying Giants marmite.

Travertine and "calcareous tufa"

The travertine formed as a result of the super saturation and the consequent precipitation of CaCO3 induced out gassing of CO2 into the water enriched in Ca2 + ions. The degassing is controlled by a complex interaction of inorganic (physical) and organic (related to biological activity), some of which are not yet fully understood (Capezzuoli & Gandin, 2004). Among the inorganic factors are of fundamental importance the variations in the CO2 partial pressure and the water temperature. Even the turbulence and evaporation of water can be used in the precipitation of travertine. The evaporation is facilitated by the presence of thresholds, where the water flows to veil, or by pulverization of water at the falls. Among the organic factors, as in the case of the deposition of calcareous silts lacustrine, it is important the role of plant organisms (micro and macrophytes) and bacteria that, by subtracting the CO2 from the water necessary for the process of photosynthesis, can trigger the precipitation of CaCO3.

The inorganic and organic factors contribute to the production of travertine, but their contribution varies depending on the type of sedimentation environment: for example, the precipitation of calcium carbonate is predominantly inorganic in the vicinity of hydrothermal sources, where the high temperatures restrict the proliferation of life.

Moving away from these, the temperatures decrease gradually until it reaches the wetlands, inland waterways, which are full of algae, macrophytes and microfite where precipitation prevail (Violante et al., 1994).

Based on these considerations, we can distinguish travertine hot and cold (respectively thermogenic and meteogenic, sensu Pentecoste - 2005): the former are bound to warm waters and have rare traces of plant organisms, while the latter are formed in the presence of cold water and their most striking feature is the abundance of deposits of plants (fitoermal travertine, sensu D'Argenio and Ferrero, 1988). Travertine "cold" is often lay along the rivers, where there are turbulent flows that promote the release of CO2 into the atmosphere.

Among the specialists he is now establishing itself notation Anglo-Saxon, which defines the continental carbonates non-thermal "reeds limestone" or "pipes" (Pedley & Ford, 1996 ;. Arenas-Abad et al, 2010), reserving the term "travertine" in carbonates only thermal origin. In this discussion, we prefer to continue to use the more familiar term in travertine, which extends to all continental carbonates epigean of chemical origin.

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6 EARTH RESOURCES

The mineral resources present in Valnerina, in the past were of particular interest to iron ores and coal mines of Ruscio (Monteleone di Spoleto).

Iron ore was extracted in centuries cast near Gavelli, just NW of Monteleone di Spoleto (in Terargo, Grotte di Luca Campofoglio and caves), around Ruscio (Cornuvole and Rescia), at Salto del cieco (Pizzo delle Ferriere) and Pupaggi (Sellano) (see details). Urban VIII the Pope had built (between 1610 and 1641) an ironworks alongside the Corno, at Ponte delle Ferriere (NE of Monteleone di Spoleto) to work the mineral. Terargo mine (geo-site 17, itinerary iron mines), which is certainly the most interesting in Valnerina area, has been in business for about 100 years in the 17th and 18th centuries. In the area of Gavelli, instead, iron is present as ferruginous concretions from the "iron of the marshes" (as the mineralization of Campofoglio di Ruscio, and Salto del cieco). In Gavelli, some surveys carried out in 1914, to a maximum depth of 26 m, found a deposit of limonite which was judged unimportant for the industry.

At 4 km South of Monteleone di Spoleto, in left of Vorga creek, 780 above sea level, the lignite mine di Ruscio is present. This Mine has been cultivated between the beginning of the nineteenth century and the middle of the last century, both in the subsoil (Talpe gallery) and two open-air sites (Scoppagamberi and Vorga). Its location, far from the centers of utilization, has always been an obstacle to its development.

Then there are small rocky material quarries. Among these, those still active Postignano travertine (Sellano), where a powerful fitotermal travertine bench was used as building stone.

Water resources are exploited for bottling of mineral waters (source Tullia in Sellano and Misia in Cerreto di Spoleto), for potable purposes (the aqueduct of Argentina, serving the towns of Spoleto, Campello sul Clitunno, is the most important) and hydro. Finally, of particular interest are the hot springs of Triponzo (11 geological site, itinerary 9), with a temperature of about 30° C.

Reading tips

A summary of available information on mines in the area, with bibliographic references is Notes of the Foglio Spoleto (Damiani, 2011). Ruscio brown coal informations are contained in the book "Ligniti e torbe d'Italia" from Ge.Mi.Na. (1962). For information on thermal waters of Triponzo, historically speaking, hydrogeological and geochemical, please refer to the work of Turchetti (2011) and "Torniamo alle Fonti" of the Umbria region (2004), as well as the “historical" work of Principi (1931). Quattrocchi et al. (2000) and Italian et al. (2004) illustrate the scope and compositional changes recorded by sources at the time of the seismic crisis of 1997-98. Also interesting is the recent "Study of the geothermal potential of the region of Umbria" (2014).

Itinerary 9 HOT SPRINGS

Along the SR 209 at about 2 km from Triponzo towards Visso, the spa facility is present under renovation (scheduled to open in the spring of 2016). Inside the structure is visible at times a spectacular pink water due to the action of sulfate-reducing bacteria.
At the height of the road bridge, on the opposite side of the road, down a lane you can come closer and touch the hot water coming out of a tunnel.

In Umbria hot springs (temperatures above 20° C) are present mostly in the Southwest, bordering Tuscany and Lazio (sources of Tiberio, Parrano). The exception is the source of Triponzo, which like that of Marche (Acquasanta) is unusual for its location within the chain.
The tour includes a visit of the sources ("baths") placed along the Triponzo SR 209 at about 2 km from the town of Triponzo in direction of Visso.

TRIPONZO SOURCES (geosite 11; sources with temperature of about 30° C)
Near Fergino Hill, there are some thermo-mineral emergencies. They provide water sulphate-alkaline earth (calcium) at a constant temperature around 30° C, regardless of the season and the weather conditions and with a capacity of 25 l/s. The water just gushes from the springs is crystal clear, with a strong odor of hydrogen sulfide, but then buy a milky appearance by precipitation of calcium sulfate and colloidal sulphur. It then leaves a whitish deposit sliding composed of calcium sulfate, which becomes green due to algae and mosses decomposed (fig. 48). Sometimes there is a pink coloration (Fig. 48b), perhaps for the activity of sulfate-reducing bacteria (Desulfohalobium retbaense are present as in a Lake of Senegal).
The springs are located at a transtensive fault system that bound a Calcare Massiccio, laterally in contact with Maiolica e Corniola Fms... The fault zone, intensely fractured, constitutes a preferred conduit for the ascent of relatively deep water, enriched in sulphate leaching of rocks of the underlying anhydrites formation of Burano (Upper Triassic). The estimated temperature is approximately 70° c. climbing inside the calcare Massiccio, the water balance at temperatures around 30°- 40° C and cold water are mixed bicarbonate-alkaline-earthy, circulating in carbonate massifs and emerging in the course of the Nera River.
The link between this source and the tectonic activity in the region has been confirmed in the phenomena observed during the Umbria-Marche earthquake crisis of 1997-98, when were recorded considerable temperature variations (reduction of approximately 20° C two days before the event of March 26, 1998), (with a decrease in the order of 70%).
Probably known since Roman times (the most famous is that mention of Virgil "amnis nar sulphur acquae," albus VII book of Aeneid lines 516-517), the "Bagni", are cited for the first time, in 1488, when, already in operation, the Bishop of Norcia Bucchi-Acciccia donated to the commune of Cerreto for 151 Gold florins. In 1862 it was performed a chemical analysis by S. Purgotti-Perugia, for which the waters were "heroic" remedy for intestinal disorders, urinary calculus, arthritis and "to all the skin diseases". In order to exploit the hydrothermal

resource, in 1887 a bath complex was built on the right bank of the Nera River, between the valley floor and the base of the Hill of Fergino.
After a period of relative minor use, attempts to boost the baths were blocked by the construction of hydroelectric plants of Valnerina, completed by the Società Terni in 1931. An underground supply channel, at the foot of Mt. Fergino, built to convey the waters of Nera (with Corno and Vigi) from Triponzo at Lake Piediluco, intercepted Karst cavities with sulphurous dramatically decreasing discharge from springs, which went from seven to five. Nevertheless the baths continued to be popular, although in a limited way, but by 1970 there has been a progressive abandonment, compounded with the 1979 earthquake. In 1985 he started a renovation project and recoupment of Terme di Triponzo (fig. 49) entrusted to RPA Perugia that proceeded in several stages with the construction of new buildings and a well for water 50 m deep around between 1993 and 1997 were physical and chemical analyses for the request to the Ministry of health permission, then granted, to perform at the Terme di Triponzo hydrotherapy, mud therapy and rinoterapiche. The earthquake of September 26, 1997 interrupted the jobs and the recovery projects. Today, the renovation for bathrooms is finally nearing completion, extended to the surrounding area as "Wellness Park".
Fig. 48-Triponzo sources. A. the Water milky and green coloration, near Parker underneath the road bridge, b. Water milky and green that becomes pink, inside the Spa.

Fig. 49-Triponzo spa complex.
ITINERARY 10 IRON MINES
The itinerary includes a visit to the iron mine of Terargo (Monteleone di Spoleto).
The mine is reached, leaving the car in Capistrello Fork (along the SP 471 of Poggiodomo) or from the Valley of Campofoglio (1263 m a.s.l.), following the path CAI n. 8 "Strada delle Ferriere". After about forty-five minutes walk (1.3 km up and then about 1 km downhill) along the path, access is visible about 50 m higher than this.
Another option is to leave the car at Butino (990 m) and follow for approximately 2.4 km to nearly steady climb up to the source Terargo (1250 m s.l.m.). From here you take the path on the right and after about 600 m of ups and downs you get to the point where you can see the entrance of the mine.
Pay attention inside the mine, we recommend the use of safety helmet and lamp.

The iron mine of Terargo (1330 m sat the foot of Birbone-Monteleone Mount di Spoleto) is the most important activity of iron ore mining in the Valnerina area.

TERARGO MINE
(geo-site 17; 17th century mine)
The mine is dug into a powerful rock mass of 10 m thickness, massive in appearance, consisting of fine-grained limestone. It is in medium-high part of Diasprigni Limestone. Outside, on the southwestern edge, you can be seen dipping fault plans to SE (fig. 50).
The entrance (A in Fig. 51), the rock mass is much fractured and has no well-defined cut planes (fig. 52). From here there are a two main galleries right into and a left onto N. The opening to the outside (B and C) is for about 5 m (height about 3 m), before a bottleneck which divides it from another stretch of about 5 m presenting another small opening (D)

and an exit to the outside to the East (and). The second gallery is divided into two after about 6 m.
On the left there is a small dark Gallery (X) 5-6 long m, where mineralized fractures are clearly visible (figs. 53a, b). After about 4 m of the second branch are visible on the left of the kerf boards with positions at a parallel prevalent tectonic lineation orthogonal to the direction of faults outside views (fig. 53). On the right, in front of these fractures, there is a very steep downhill tunnel.
Continuing to penetrate inside the mine, a large open room has a height of more than 4 m and has an opening in the canopy (H). From this room, 4 more galleries radiated, placed a greater share (you can reach up about 2 m), of which those in the North have carbonate concretions. The Western Gallery (s) cannot be reached easily due to a bottleneck that prevents the transition, while the Eastern Gallery is divided into two with the left branch that has an opening in the canopy (G) and the one on the right that leads to the outside (F). To N there are two more galleries that have carbonate concretions, due to the constant percolation of water.

Fig. 50-fault plane on the southwestern edge of the mine
Fig. 51-floor plan and sections of Terargo Cave
Fig. 52-Terargo iron mine.
Fig. 53-Terargo iron mine. A, b. mineralized Fractures in the Gallery (see map in Fig. 51), c. mineralized fractures in the gallery leading to the largest room of the mine (see map in Fig. 51).
Fig. 54-diffraction analysis results performed on a sample taken in the Terargo mine at the laboratory of the Department of Physics and Geology at the University of Perugia (blue peaks of goethite, red calcite).

DEPOSITS AND IRON MINES IN UMBRIA

The Apennines has some small iron deposits exploited in historical times (Monte Cucco, Sellano, Monteleone di Spoleto and Narni). The most important is Monteleone.

The map shows the iron ore deposits in Umbria (red circles indicate the iron, fluorite pink ones and those orange gold).

Matteo Barberini, Bishop of Spoleto, during his pontificate (Pope Urban VIII, 1623-1644), commissioned the cardinal Fausto Poli Usigni to start mining activity, which was to follow the manufacture of iron. Between 1630 and 1641 (Morini, 1903) were made the only ironworks of the Papal site in Ponte delle Ferriere, a hamlet of Monteleone along Corno river (Cavallini, 1999). Later (in 1635) it was also built an ironworks in Scheggino, which remained in business for a few years.

The extraction has been important for the economy of this area, infact under Pope Clement IX (1667-1669), had the highest production of iron. The iron of Monteleone was used, among other things, to make the gates that closed the Pantheon until 1883.

The extracted material was subjected to a first transformation on site and then transported with carts and animals. Later, new roads have been built to transport the finished material, as the road from the Flaminius Valerian in Monteleone and then continue to Cascia and Norcia, passing over a bridge in the Corno River called Ponte delle Ferriere.

The high costs of extraction and transportation of iron, the earthquakes of 1703 and 1730 (with many victims) and the plague of 1718, contributed to the inexorable decline of mining in Monteleone (Cavallini, 1999). Other mines were active in historical times in Umbria: Monte Cucco (Cave Railway track with sulphates, sulphides and hydroxides of Fe and plaster, with underground mining in the fifteenth century and Buca Iron Costacciaro, Cava del Ferro, in the municipality of Gualdo Tadino with underground mining for several years in the nineteenth century), and those present at Stifone (Narni), who in the eighteenth century was also an important ironworks.

As for the source of the iron deposits in Umbria, we can certainly say that the open pit mining deposits (Gavelli, Pupaggi, Ruscio) have exploited remaining assets (limonite) in lake sediments "Iron swamp". Underground mines (Terargo, Monte Cucco, Gualdo Tadino, Stifone) have exploited all the mineralization in Jurassic rocks present at the contact between Calcare Massiccio and Bugarone, or fractures in parallel a major tectonic lineations. In the first case the mineralizations are probably of the primary generation, while in the second case deposited to lift fluids fortified with iron along faults Jurassic. These mineralizations (oxides and iron sulfides) have been subsequently modified on the hydroxides and sulfates. Particularly interesting is the presence of some sites (Terargo and Cave of Faggeto Tondo Monte Cucco) with the presence of fluorite and fluorapatite, hydrothermal minerals (hydrothermal). Finally, note the presence of volcanism pleistocenic (Polino) and thermal anomalies (source Triponzo 30 ° C, the source of Stifone 19 ° C).

Commemorative Medal of Pope Urban VIII, on the reverse front are visible some miners (m. Angelini properties). Photo by: www.archeoambiente.net.

Gates of the Portico of the Pantheon (until 1883).

Photo by: www.archeoambiente.net.

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