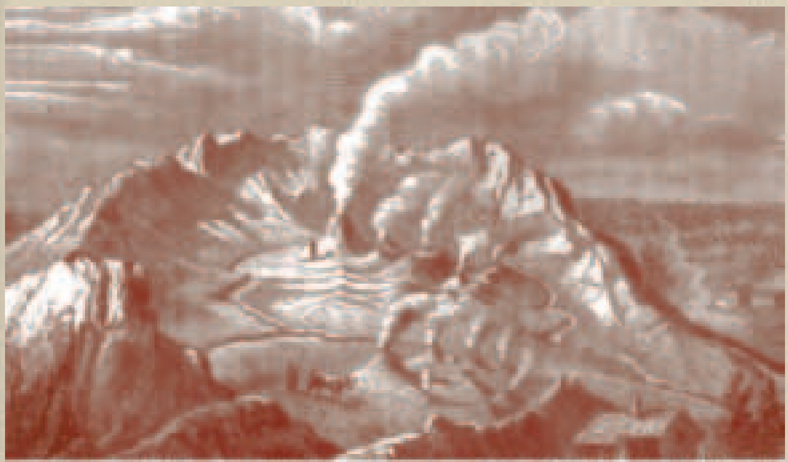
Volume n° 1 - from PR01 to B15

32nd INTERNATIONAL GEOLOGICAL CONGRESS

GEODIVERSITY IN THE LANDSCAPE OF EMILIA-ROMAGNA (NORTHERN ITALY): GEOSITES IN THE APENNINES BETWEEN MODENA AND REGGIO EMILIA



"Era la gran salsa di Nirano. Immaginatevi una specie di gran circo o d'anfiteatro, come sarebbe l'Arena di Milano, ma assai più vasto, costituito da una landa deserta, chiusa da un ampio recinto che la circonda quasi d'una muraglia di cenere."

"This was the great Nirano mud volcano. Imagine a sort of large cirque or amphitheatre, like the Milan arena but much bigger, made up of barren land, confined by a vast barrier, a sort of wall of ashes."

Leader:
S. Piacente

Associate Leaders:
M. Pellegrini, P. Coratza

Field Trip Guide Book - B06

Florence - Italy
August 20-28, 2004

Pre-Congress **B06**

The scientific content of this guide is under the total responsibility of the Authors

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GEODIVERSITY IN THE LANDSCAPE OF EMILIA-ROMAGNA (NORTHERN ITALY): GEOSITES IN THE APENNINES BETWEEN MODENA AND REGGIO EMILIA

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Front Cover:
Original drawing by Stoppani (from "Il Bel Paese, 1878)
representing the Nirano mud volcanoes.

Leader: S. Piacente
Associate Leaders: M. Pellegrini, P. Coratza

Introduction

Maurizio Pellegrini and Sandra Piacente

The excursion proposed is part of the Italian Research Project "Geosites in the Italian landscape: Research, assessment and improvement" whose national coordinator is Sandra Piacente. This Project intends to offer a methodological pathway for better understanding and appraisal of our geologic heritage, considered a Cultural Asset. One of the most innovative concepts resulting from this research is certainly the idea of "Geo-diversity", which considers the variety of geologic environments and relief forms as the basis for the variety of life on Earth, in a concept that also integrates social and cultural structures (Piacente and Poli, 2003).

Today, people seek new and higher-quality elements in their life which, paradoxically, are the most natural and primordial: clean air, sunshine, landscape, quietness, emotional satisfaction. Geodiversity stands out as a powerful element in an integrated information system which, unfortunately, has been poorly developed so far. "Developing" means, first of all, communicating: successful, well-targeted communication is the first step in a lasting appreciation that all would share. "Developing" also means trying out new paths, even if indirect, involving the affective realm, emotional relationships. In the case of Geodiversity, operational proposals should be defined, which, besides promoting new ideas and opinions, would acquire a deeper social value. In this way, knowledge would become the rational basis from which to create a logical policy of correct use, conservation, and improvement. This can be achieved by means of intelligently integrating protective interventions of areas of cultural, socioeconomic and tourist importance.

In some European countries geoconservation has been the object of various norms since the early 20th century. Nevertheless, the first European Association for its advancement (the European Working Group for Earth Science Conservation) was founded only in 1988, and renamed ProGEO in 1993. In 1996, thanks to the initiatives of the IUGS under the patronage of UNESCO, the "Geosites" project was started, with the specific goal of implementing a computer-based archive of the world's most important geologic sites. Finally, in 2001, the International Association of Geomorphologists (IAG) established the "Geomorphological Sites" Working Group (Piacente, 2003).

There is now the opportunity to launch the subject of Earth Sciences into new areas which could enhance its cultural and social links. Naturally, these prospects will become reality only if the philosophy of geoconservation is not restricted to specific elitist areas but, instead, if spreading geosite knowledge and awareness becomes a constant practice.

The geosites visited during this excursion are mostly included within cultural-tourism itineraries, some of which, such as "The Devil's Stones amidst hamlets and castles of the Emilia Apennines. A cultural itinerary in the ophiolite landscape" (Bertacchini *et al*., 2003) and "Cultural Landscapes between Geology and Literature in the 20th century in Emilia-Romagna" (Bertacchini *et al*., 2002b) were produced in collaboration with the Emilia-Romagna Region. The participants will be shown not only the scientific aspects of these geologic outcrops but also related historical-cultural aspects (castles and watch towers, cultural and economic contexts, as well as literary references). This excursion also includes a visit to other particularly spectacular geosites of paramount importance for understanding the geologic evolution of our region (Piacente *et al*., 2003).

Those who would like to follow the itinerary on their own, starting from Bologna, should know that the area involved has a good road network, although traffic can be rather heavy and slow. Restaurants with typical Italian and, in particular, regional cuisine are numerous along all the itineraries proposed. Also, hotels (mostly three-star ones) are fairly common, and most of them are open all year-round. The only period unsuitable for the visit is late autumn, owing to frequent rains. In winter, snow has appeared only on rare occasions in recent decades, while clear, bright days are frequent. We advise the purchase of a 1:200,000 scale Road Map edited by the Italian Touring Club ("Emilia-Romagna" Sheet; web site www.touringclub.it. More detailed topographic maps (1:25,000 to 1.5,000) can be purchased from the Geological Survey of the Emilia-Romagna Region or on the web site: www.regione.emilia-romagna.it/carto/reper/defaulta.htm. At the same office it is also possible to purchase the related geologic maps: the new sheets at a 1:50,000 scale (Sheet numbers 218, 219, 220 and 236 will be available late in 2004), and also some geologic sections printed at a 1:10,000 scale. Legends are in Italian, but in the regional-scale maps an English translation is provided. For a regional geologic framework, it is advisable to

purchase the following geologic guide (in Italian) which can be ordered from any book shop:
Bortolotti, V. (1994). Appennino tosco-emiliano. 12 Itinerari. Guide Geologiche Regionali, Volume nr. 4, 2nd edition, Società Geologica Italiana, Rome.

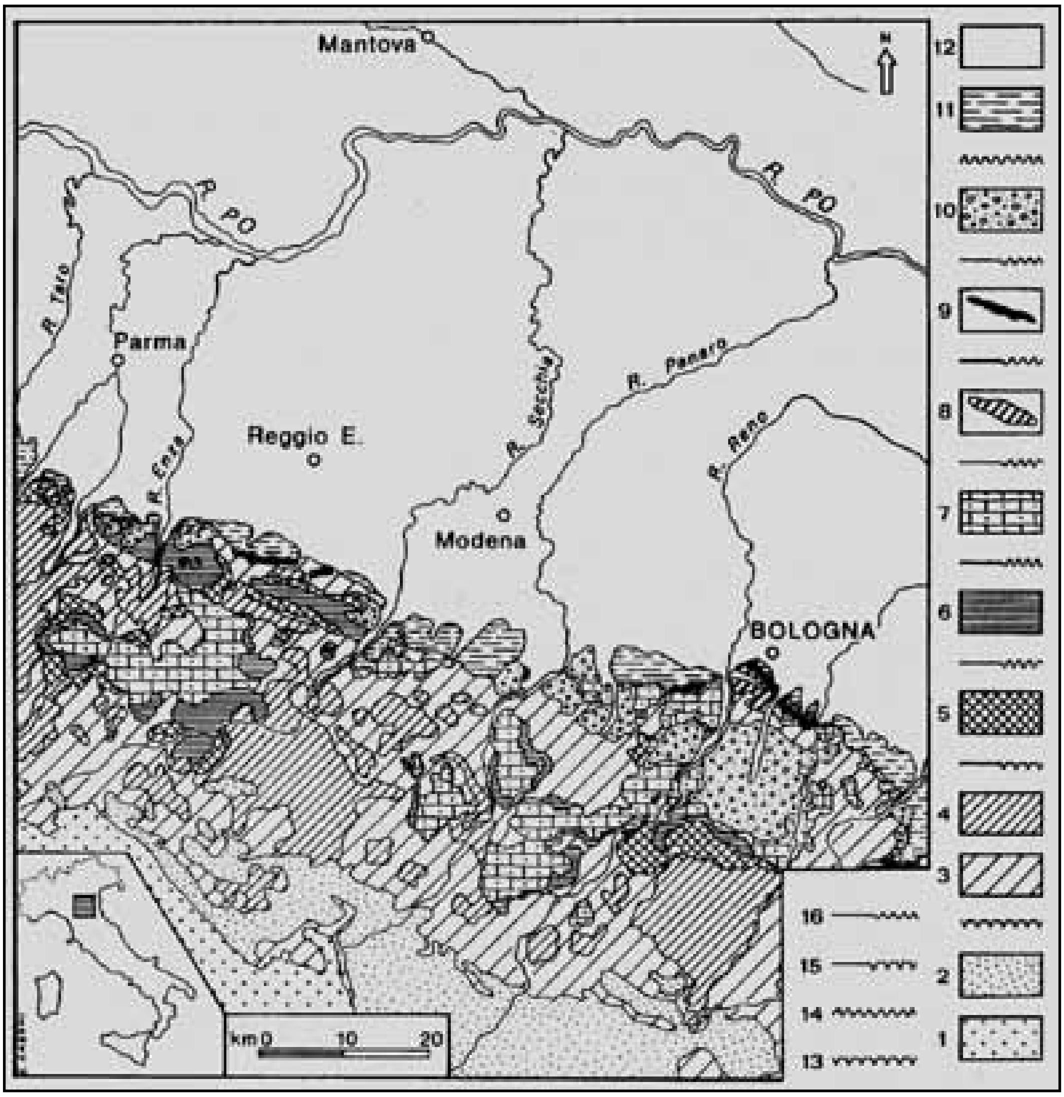


Figure 1 - Geologic sketch of the Northern Apennines and Po Plain: 1. Macigno (Late Oligocene-Early Miocene) arenaceous Flysch; 2. Mt. Modino. Mt. Cervarola arenaceous Flysches (Late to Early Miocene); 3. Ligurian Units (Cretaceous-Eocene): Mainly shaly sequences of the basal complexes (Varicolori and Palombini Formations; 4. Ligurian Units (Cretaceous-Eocene): Calcareous and arenaceous Flysches; 5. Epi-Ligurian Units (Oligocene-Late Miocene): Sandstone and clay shale sequences. 7. Epi-Ligurian Units (Early-Middle Miocene): Terrigenous and bioclastic calcareous sandstones; 8. Clay and claystone sequence (Tortonian); 9. Gypsum, clay, conglomerates, evaporitic limestones (Messinian Formations); 10. Intra-Apennine Plio-Quaternary Marine Sequence: Conglomerates, sands, silts and clays; 11. Marine Sequence of the Apennine margin (Pliocene-Pleistocene): Mainly claystones; 12. Quaternary alluvial deposits of the Po Plain: Gravels, sands, silts and clays; 13. Unconformity; 14. Stratigraphic boundary with hiatus; 15. Partial unconformity; 16. Partial hiatus (after Pellegrini and Tosatti, 1992).

Regional geologic setting

Maurizio Pellegrini

The excursion will take place along the northern foothills of the Northern Apennines, adjacent to the Po Valley, across the Emilia-Romagna Region (northern Italy) provinces of Bologna, Modena and Reggio Emilia (Figure 1).

The Northern Apennines are a fold and thrust belt of complex origin and evolution, resulting from the collision of the Adria Plate with the European Plate, starting from the Late Cretaceous, with the consequent closure of the "Ligurian-Piedmontese" oceanic basin, which was located in the western Tethys (Elter 1973, 1994; Boccaletti *et al*., 1987). At first this closure caused the formation of an accretionary prism, in which many tectonic-stratigraphic units can be distinguished. They are linked to two processes: 1) the sedimentation in either an oceanic environment or a plate-margin continental environment; or 2) to the progressive consumption of the Ligurian oceanic crust (Principi and Treves, 1984; Treves, 1984).

In the Northern Apennine area here considered, the various tectonic-sedimentary units which form the backbone of this chain, can be categorized in the following way, from the bottom to the top:

• ***Tuscan Units***: these originated in the Tuscan Domain and were incorporated in the passive margin of the African Plate, which was involved in various Tertiary collisional phases. They include the Apuan Metamorphic Complex and the Tuscan Nappe.

• The ***Sub-Ligurian Unit***: this is situated between the Ligurian Domain and the Tuscan Domain. It is made up of Tertiary argillite-calcareous sequences at the bottom, and siliciclastic sequences at the top.

• ***Ligurian Units***: these are entirely included in the Ligurian Domain. In relation to their different types of substrata, they have been divided into Inner Ligurids (deposited on oceanic crust) and Outer Ligurids (deposited on prevalently continental crust, or, in some cases, also on transition crust). The former are found prevalently in Liguria, whereas the latter are widespread on both the Tyrrhenian side and the Po Valley side of the Northern Apennines (Figure 1).

Contrary to the above described order, the formation of the fold and thrust structure of the Apennines shows that, in their present geometric conditions, the Ligurian Units are placed on top of this piled-up structure in an "external" position, since they overthrust both the units belonging to the Sub-Ligurian Domain and the Tuscan Domain.

Following the post-Tortonian compressive phase, the Apennines were affected by a new extensional phase, which in the internal part of the chain gave origin to subsiding basins with both marine and continental sedimentation.

On the Po valley side of the chain, various sequences which originated in intra-Apennine basins, and which are usually known as *Epi-Ligurian Units*, unconformably overlie the Ligurian Units. The deposition of the Epi-Ligurian Units was subsequent to the Ligurian tectonic phase (Middle Eocene) and ended in the Tortonian. Since these units followed the geologic evolution of the Ligurian substratum progressively moving to NE, they are considered "semi-allochthonous". The outcrops of the sequences corresponding to the Epi-Ligurian basins show varied extension, orientation, shape and thickness; we will find these outcrops throughout the territory of our two-day excursion.

The ***Tuscan Nappe*** tectonically overlies the Apuan Metamorphic Core and is partially covered by remnants of the Canetolo Unit and the External Ligurian Units. It is made up of a sequence of prevalently marine formations, ranging in age from the Late Triassic (the opening up of the Tethys) to the Early Miocene. The basal portions of the sequence are made up of carbonate, calcareous-silico-marly and hemipelagic deposits and crop out in Tuscany. The uppermost portion of the Tuscan Nappe crops out along the Apennine crest, which makes up the watershed between the Tyrrhenian and Adriatic basins. This top portion of the sequence is mainly composed of arenaceous-pelitic turbidites ("Macigno" and "Arenarie di Monte Modino"), Late Oligocene-Early Miocene in age.

Similarly to the Apuan Metamorphic Complex, the tectono-sedimentary evolution of the Tuscan Nappe is also linked to the geodynamic evolution of the Adria Plate's passive continental margin during the opening and closing phases of the western Tethys, as well as to the subsequent migration to the east of the Northern Apennine chain-foredeep-foreland system from the Middle Eocene to the Early Miocene. Therefore, within this context, the foredeep basins were subject to an eastward displacement and are characterized by turbiditic, siliciclastic deposits and olistostromes ("Arenarie di Monte Cervarola").

The ***Sub-Ligurian Unit***, which is found on both the Tuscan and Emilia side of the chain and is known in the literature as "The Canetolo Complex" or "The Canetolo Unit" (Zanzucchi, 1963), is composed of an essentially Paleogene sequence dominated by argillites, micritic limestones and calcarenites, as well as calcareous-pelitic turbidites ("Argille e calcari di Canetolo"). The various sequences of this unit show numerous sedimentary and structural complexities (boudinage, discontinuous bedding, channelised or turbiditic bodies, mélanges, intense jointing, widespread minor folds and thrusts etc.). All these structural characteristics resulted from the complex tectono-sedimentary events occurring during the displacement of these sequences on top of the Tuscan Domain formations (Montanari and Rossi, 1982; Labaume, 1992).

The ***Ligurian Units***, which are found both in Tuscany and Emilia-Romagna, are the most extended units in the western portion of the Northern Apennines and, together with the overlying and unconformable Epi-Ligurian sequences, make up the structural top of the Apennine chain. As said above, the Ligurian Units have been subdivided into Internal Ligurids, owing to the presence of an oceanic substratum (with ophiolites in the foremost position), and External Ligurids, owing to the absence of a substratum, which instead appears at the bottom of the various sedimentary sequences, such as the Rossena ophiolites.

In their upper part, the External Ligurids, which extensively crop out also in the lower Apennines of the Bologna, Modena and Reggio Emilia provinces, include numerous Late Cretaceous and Paleogene tectonic Units. The External Ligurids are made up of thick, monotone marly-calcareous, turbiditic sequences (Helminthoid Flysch *Auctt.*) and matrix-supported or clast-supported detrital deposits (Basal Complexes *Auctt.*). The latter usually correspond to the so called "Argille scagliose" *Auctt.* (= scaly clay shales). On the whole, the various Units form a dismembered and complex structure, in the sense that homologous or identical units may be positioned differently compared to their position in other Units. A recent article (Bettelli and Vannucchi, 2003) has described the structural style of the oceanic sequences of the Ligurian Units, and the sedimentary origin of their mélanges.

The basal and top portions of these units are characterized by rock types with a high contrast of competence. Furthermore, in proximity to the boundary between the basal Complexes and the overlying flysch units, a permeability threshold is found; this is the source of many significant landslides in the Emilia Apennines (cf. Bertolini *et al.*, 2001).

Finally, it should be remembered that the tectonic phases which affected this chain have considerably influenced the mechanical behavior of these formations. As a consequence, if one considers also the intense processes of physical-mechanic weathering, the behavior of the Ligurian Units is more similar to a soil aggregate rather than a sound rock body. The weathering of not only these geologic formations but of most of the landforms observable today is also the result of the climatic changes occurring in the Late Pleistocene and Holocene: in the Apennines two cold periods have been recorded, corresponding respectively to the Riss and Würm of the Alpine chain.

Epi-Ligurian Units. The final closure of the Ligurian oceanic basin, and the consequent build-up of the orogenic wedge, were the result of the main Apennine tectonic phase of the Mid-Early Eocene (the "Ligurian phase" *Auctt.*). This latest structural arrangement led to the formation of new sedimentary basins on the deformed Ligurian bedrock. Some of these basins were formed on the accretionary prism whereas others originated as piggy-back basins on the front of the most advanced thrusts; hence the name "Epi-Ligurian" given to these sequences by Ricci Lucchi and Ori (1985).

The time span of the Epi-Ligurian sequences ranges from the Middle Eocene to the Late Miocene. They are therefore partially coeval with other rock types belonging to the previously described Ligurian Units. Nevertheless, hardly ever is the sequence complete since some of the bottom or top formations are often missing. Some Epi-Ligurian basins are considerable, both in extension and thickness, whilst others are rather small.

The formations making up the Epi-Ligurian sequence are numerous, and vary according to the different positions of the basins compared to their original sedimentation sources: the thick Ranzano and Loiano arenaceous formations (Early Oligocene), with their underlying argillite formations ("Argilliti di Rio Giordano" and "Marne di M. Piano") from the Mid-Late Eocene are particularly of note.

In the Emilia Apennines the sequences of the Epi-Ligurian basins terminate with the Bismantova Group, which unconformably rests on a silicified mudstone formation. This group is made up of two formations: the Pantano Formation and the Cigarello Formation, belonging to the Late Burdigalian-Early Langhian and Early Langhian-Serravallian, respectively (Bettelli and De Nardo, 2001, and related references). The former formation is made up

of a series of siliciclastic and bioclastic sediments, whereas the latter consists of massive, grayish, marly-silty bioturbation deposits, alternating with pelitic-arenaceous and arenaceous bodies.
The Epi-Ligurian Units, typified by a certain degree of allochthony, mostly characterized by mild synclines with brittle behavior, underwent a less intense tectonic displacement than the Ligurian bedrock.
At the Po Valley foothills, marine Plio-Pleistocene argillaceous and sandy sequences crop out. They "seal up" the Apennine outcropping front and cover it in the subsoil of the plain (the Epi-Tuscan Domain). East of the Panaro River Valley, in the Bologna province, similar and partially coeval rock types are instead found on top of the Epi-Ligurian Sequences of the Apennines, since sedimentation within the satellite basins lying on the displaced Ligurian bedrock continued until the Mid-Early Pleistocene. Along the Apennine foothills, the grayish-bluish clays of the Plio-Pleistocene cycle have formed a typical badland morphology, with deep gully erosion and very interesting outcrops, like those that will be observed near Salse di Nirano, during the first-day's excursion.
The Apennine chain continues underneath the Pliocene and Mid-Early Pleistocene marine sandy and clayey formations as well as underneath the Late-Pleistocene and Holocene alluvial deposits of the plain, forming huge fold and fault systems and north-verging thrusts. The front of the chain is located just north of the Po River, some 35 km from the foothills, that is, from the outcropping side of the chain (Castellarin *et al*., 1985).

Field Itinerary

DAY 1

(Bologna – Bazzano – Savignano sul Panaro – Guiglia – Rocca Malatina – Samone – Ponte di Samone – Vignola – Maranello – Spezzano – Salse di Nirano – Spezzano – Modena) Figure 2

From Bologna Railway Station (Bologna Centrale) follow the ring road in the direction of Modena-Milan, heading towards Bazzano, across an intensely developed area. After Bazzano (a medieval castle with an interesting small archaeological and geologic museum) go on towards the foothills where late-Pleistocene relict surfaces (terraces) can be observed. Continuing towards SE, through Savignano sul Panaro, take the turning for Guiglia and, when the road starts going uphill towards Guiglia, the gravelly bed of the Panaro River can be seen on the right-hand side. In Guiglia (which has an interesting castle and hamlet with buildings mainly dating back to the XVII and XVII centuries) calcareous limestones of the Bismantova Group (Mid-Early Miocene) can be observed. Finally you'll come to Rocca Malatina with its rocky cliffs known as "Sassi di Rocca Malatina" (**Stop 1**).

From the "Sassi di Rocca Malatina" proceed across outcrops of the Bismantova Group formations to the hamlet of Rocca Malatina, an ancient fief of the Malatigni family, whose territory in 1420 was guarded by four strongholds, as far as Samone (**Stop 2**).

After a series of hairpin turns you'll come down to Ponte di Samone, a bridge on the Panaro R., with panoramic views of the riverbed and of the opposite slope, which is characterized by large earth flows. Along the road *Argille varicolori* (polychromic clay shales) can be observed with their typical red beds, together with other formations from the Ligurian Units.
In Vignola (where there is a very interesting and well-preserved medieval castle with a Renaissance palace nearby), one can see the Panaro R. terraces, which are largely cultivated as orchards (cherry trees). In the distance, on the right-hand side, badlands are visible in the marine gray clays of the Plio-Pleistocene cycle. Between Vignola and Maranello you'll be travelling across wide, terraced surfaces, with farmland and vineyards (Grasparossa or Castelvetro Lambrusco wine). Notice the reddish-brown paleosoils; these are ascribable to the Late Pleistocene. On the left-hand side there is a pleasant view of the foothills.
In Spezzano turn to the south, following the narrow valley of Fossa Creek, eventually reaching the parking lot of the Natural Reserve of Salse di Nirano (**Stop 3**).

The first day itinerary ends with our return to Modena, travelling north across a very flat alluvial plain, characterized by Holocene alluvial deposits, mainly pelitic. This area has undergone intense development. Near Spezzano one can see many industrial buildings for the production of ceramic tiles (as this is the "Sassuolo ceramic tile district").

The sites visited during the first day have been selected and scientifically evaluated as Geological

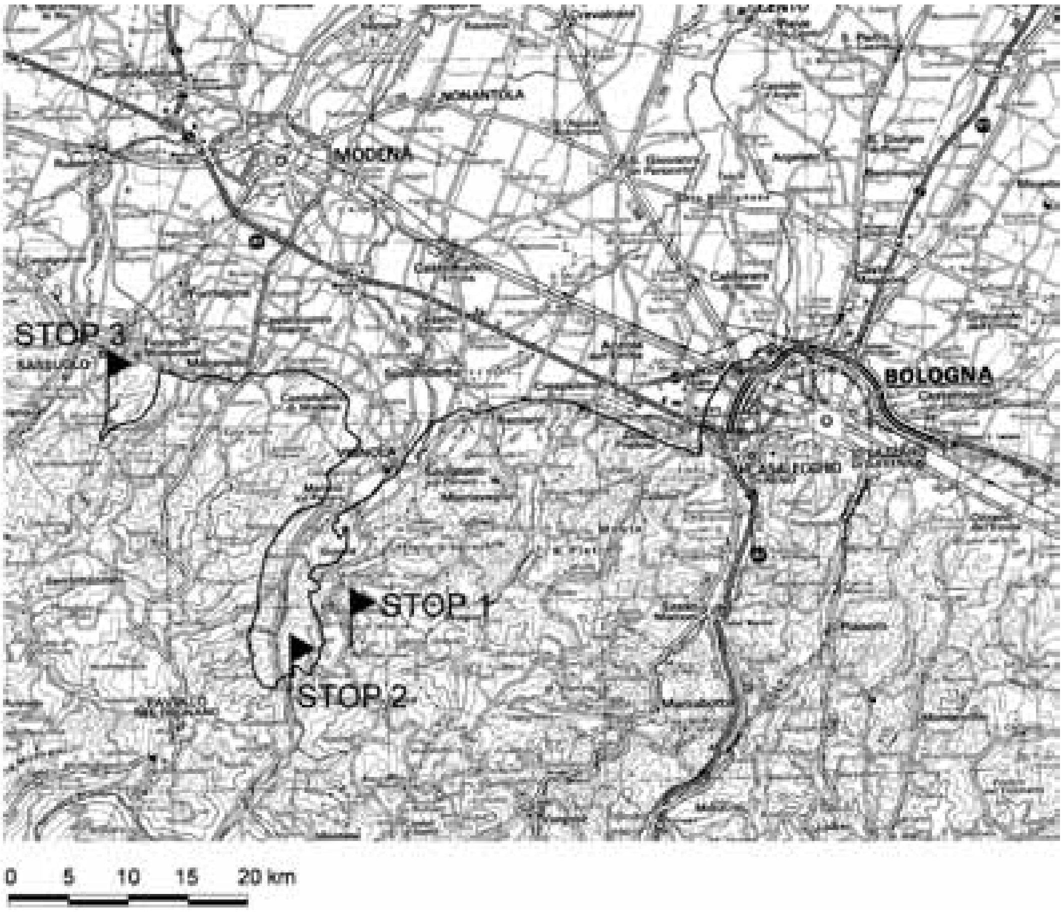


Figure 2 – Itinerary of the first day

Assets during investigations carried out over the territory of the Modena Province. These sites have been described from a scientific standpoint in a volume (Bertacchini *et al.*, 1999a) containing a census and an assessment of the Geosites of the Modena Province.

Stop 1:

The "Sassi di Rocca Malatina"

Maurizio Pellegrini and Giovanni Tosatti

The "Sassi di Rocca Malatina" are with no doubt one of the most relevant landforms of the entire Emilia-Romagna Apennines. They characterize the landscape of the mid-Panaro Valley, since they are observable from a long distance from both the valley floor and the opposite slope. From the hamlet of Rocca di Sotto – located next to these sandstone pinnacles – there is an excellent panoramic view of these landforms. From where the bus stops near a bar-restaurant, you can proceed on foot towards a chapel (the Oratorio di Rocca di Sotto) and, following along a steep footpath, reach the summit of one of the cliffs (Sasso della Croce) in about ten minutes (Bertacchini *et al*., 1999b) (Figure 3).

The Sassi di Rocca Malatina are made up of a group of spectacular sandstone pinnacles, over 70 m in height, characterized by marked steepness: their slope acclivity is in sharp contrast with the mild morphology of the surrounding clayey outcrops, which are instead characterized by extensive landslides and badlands, typical of the clay-shale formations of the Ligurian Units of the Northern Apennines.

These rocky cliffs have been modeled from grayish or yellowish, often weathered, coarse to fine-grained, quartz-feldspar sandstones which, from a stratigraphic viewpoint, correspond to the Anconella Member (Burdigalian) of the Antognola Formation (Oligocene-Miocene). This member consists of a rock body, easily recognizable thanks to its lithology and its textural organization into thick, graded layers resulting from re-sedimentation processes subsequent to submarine flows in a shelf-basin environment. This sandstone member is intercalated in the upper part of the prevalently-pelitic Antognola Formation, belonging to the Epi-Ligurian Sequence. Its strata do not usually show inner structures: they are just graded and, in some places, parallel-laminated (Bettelli and Bonazzi, 1979; Bettelli *et al*., 1989).

The morphology of these rocky cliffs is derived from selective erosion, mainly controlled by lithologic characteristics, since the "Sassi di Rocca Malatina" consist of sandstones resting on clays and clay shales. Their shape is also due to the subvertical attitude of the strata which makes them more resistant to erosion and inhospitable for the vegetation. In fact, where the strata arrangement changes, the sandstones no longer show such an exceptional and unique shape. Like other sandstone outcrops of this area, the "Sassi di Rocca Malatina" are characterized by high permeability, so that springs are often found at the sandstone/clay boundary. Where the sandstone cement is weaker, the rocks do not present such a compact texture and, therefore, they are more exposed to weathering and degradation processes. In fact, meteoric agents have shaped several detachment cavities. The morphologic evolution of these formations is also controlled by the widespread presence of tectonic joints, giving rise to rock and debris falls.

These erosional forms are well exposed along the footpath that leads to the top of the main pinnacle. Bear in mind, however, that these cliffs have certainly been shaped also by human intervention.

South of this group of cliffs, at the bottom of "Sasso della Croce", two "pseudo-karst" cavities are found: they are named "Buco dei Falchi" (= "hole of the falcons") and "Buco del Casone" (= "hole of the big house"). From their shape one might deduce that they are karst landforms but, on the contrary, they have nothing to do with this process. The former, which is 18 m long with a difference in elevation of 6.5 m, was formed along a joint in the sandstone and was subsequently enlarged owing to meteoric weathering and erosion. The latter is some 5 m long, and was formed in the same manner as the first.

This area is of great interest for many reasons. First of all, the presence of these spectacular pinnacles offers numerous related micro-environments. Furthermore, the area presents a harmonious balance of woods and farmland, with architectural elements. Lastly, past and present human activities, the folk traditions, all contribute to the extreme interest of this setting.

Figure 3 - "The Sassi di Rocca Malatina" (photo by M. Panizza)

The presence of all these valuable elements led to the creation of a Regional Park (established by Emilia-Romagna Regional Law # 11/1988, later modified and integrated by Regional Law # 40/1992). Unfortunately, though, in the '60s, permission was granted for the construction of a ghastly restaurant called "Il Faro" (= the Lighthouse!) in a very close position to the "Sassi di Rocca Malatina". From a scenery point of view, this building is a real eyesore since it is visible from any observation point.

The vegetation is typical of the middle mountain area, with oak groves associated with particular micro-climatic conditions. Many parts of these woods show the ecological characteristics of mesophyll vegetation, dominated by the common oak (*Quercus robur*), even if in some dry soils and slopes xerophyll oak groves thrive. Among the xerophyll shrubs associated with the pubescent oak (*Quercus pubescens*), numerous specimens of juniper (*Juniperus communis*), broom (*Spartium junceum*), arboreous heather (*Erica arborea*), and Italian helichrysum (*Helichrysum italicum*) are present.

Another important tree in the park is the European

chestnut (*Castanea sativa*), with several specimens over one-hundred-years old. Since remote times this tree has been cultivated as a food source. On the shady and damper slopes, and in the more sheltered crevices, specimens of the beech tree (*Fagus silvatica*) and bilberry shrubs (*Vaccinium myrtillus*) are also found.
Among birds of prey, worthy of note is the fairly common presence of the peregrine falcon (*Falco peregrinus*), which is very rare in other areas of the Apennines. This noble bird, which is also the symbol of this regional park, nests in the numerous cavities found along the cliffs' walls.
Although the peculiar geomorphologic features of the "Sassi di Rocca Malatina" are the most interesting aspect of this regional park, an excursion in the area is highly recommended also for all the natural and architectural elements previously mentioned, in particular, during the blossoming of the Panaro Valley cherry trees (early April). Among the numerous buildings of historical interest, worthy of note is the old hamlet of Rocca di Sotto. This is an ancient fortified village which still preserves its original medieval town planning arrangement. Numerous buildings have been built with sandstone and are worthy of attention owing to their portals, freezes and other ornamental elements, like the XIV century portal in the largest building. The annexed chapel shows features resulting from its restoration, carried out in 1855. Worthy of note is also the famous Romanesque church of Pieve di Trebbio (XI century) with a massive tower and a baptistery (Various Authors, 1991; 1992).

Stop 2:
The "Dolines" of the calcareous-arenaceous slab of Zocca-Guiglia, near Samone
Maurizio Pellegrini

The Epi-Ligurian "slab", cropping out in the area between Zocca and Guiglia, in the eastern sector of the Modena Apennines, is topographically higher compared to the surrounding landscape, which is mostly characterized by the clayey formations of the Ligurian Units. The latter extensively crop out along the right-hand side of the Panaro Valley. The Zocca-Guiglia arenaceous plateau is mainly made up of arenaceous and marly rock types of the Bismantova Group and the underlying Antognola Formation. The former either form tabular structures or are slightly deformed as mild synclines, dismembered by numerous faults and joints resulting from the various tectonic phases which led to the formation of the Apennine chain (Bettelli *et al*., 1989). Owing to its rigidity, this slab is subdivided into several blocks along shear surfaces. In addition, its considerable weight causes the outflowing of the underlying clayey soils of the basal complexes (Ligurian Units), which show a plastic pattern of deformation (Cancelli *et al*., 1987). In one case, these clayey soils are pushed upwards, forming a sort of sub-circular intrusion, some 100 m wide, completely surrounded by sandstones of the Bismantova Group. This particular feature, which is observable near the Fosso degli Specchi stream, north of the village of Samone, is assumed to be a relevant example of diapirism, which is a passive upwards displacement of the underlying clayey soils, "squeezed" by the heavy arenaceous blocks surrounding them.
The landscape inside this arenaceous plateau is characterized by mild relict landforms, which are ascribable to modeling processes no longer active, probably occurring in a periglacial environment during and immediately after the last Würm glaciation. Nevertheless, karst-like forms make up the most considerable morphologic features of this slab. These forms are extensively developed and show great typologic variety: dolines, sinkholes and rock shelters. The highest concentrations of doline-like depressions are found near the villages of Guiglia, Rocca Malatina and Samone. This last one is also the second stop of the day. The development of these landforms, though, is only partially due to the dissolution of calcium carbonate from the clasts and cement of the Bismantova Group arenites (the Pantano and Pietra di Bismantova formations). In many cases, they are simple chimneys (vertical holes) associated with piping processes, which have been developed along mechanical joints induced by gravitational deep-seated slope deformations. The effects of gravitational displacements are particularly evident along the slab's outer margins, at the boundary with the underlying clayey soils (cf. Cancelli *et al*., 1987; Bertolini and Pellegrini, 2001). Therefore, in many cases, all these cavities are the result of processes which only apparently give rise to karst-like landforms. More accurately, they should rather be defined as "pseudo-karst" landforms. In other cases they are the result of "para-karst" processes. In other words, they are the product of weak karst processes and are related to the rather scarce carbonate content of these Miocene arenites.
Dolines are present in varied shapes and dimensions,

and are sometimes accompanied by sinkholes. Some of these elongated depressions drain considerable areas, with differences of elevation up to 70-80 m. The most common forms found are dish- and bowl-like shapes. Generally, all dolines are bounded by joints which confer them a typical elliptic shape. Ocher-colored decalcified material is often found on the dolines' floor.
Indeed, the most relevant groups of dolines and other karst-related landforms of the Province of Modena are observable near the sport facilities area of Samone and at Serre di Samone. From the interesting old buildings of Serre Samone – including an important country house with annexed service buildings and a chapel – some easy trails, leading NNW, take us to where, after a few minute walk, several dolines are found. In some cases, sinkholes are observable on their bottom. On the western slab's margin some 15 sinkholes are found, with a maximum length of 65 m and a difference in elevation of 14 m. These cavities host a very interesting fauna, with an endemic species of insect: the *Duvalius malavolti* coleopteran. All these vertical cavities are, in fact, pseudo-karst forms, resulting from the tectonic joints being widened by the detachment of a large rotational slide, which has also affected the underlying argillaceous soils. Water from precipitation, after percolating through the Serre di Samone dolines, emerges at two tapped springs along the Gainazzo road.
A fine example of para-karst form is found east of the village of Samone: the "Lago dell'Acqua" doline (which will not be visited due to logistical reasons). This place name (the "Lake of Water") represents the geomorphologic situation of the area, characterized by a 200 m long, E-W elongated depression which, during the rainiest periods of the year, is filled with water. Unfortunately, this small pond has recently been altered by human intervention, and is now used as a reservoir for farming practices.

Stop 3:
The Natural Reserve of the Nirano Mud Volcanoes
Giovanni Tosatti
Mud volcanoes are the product of pseudo-volcanic activity consisting of the emission of liquid and gaseous hydrocarbons mixed with cold, salty muds. They develop into either cone-shaped vents (Figure 4) or mud pools (Figure 5), and are often located on top of recent sedimentary formations, where high pore fluid pressures are found. These high pressures result from the difficulties found by the fluids, contained within the sediments, while trying to escape towards the surface, especially when the rock types are mainly argillaceous, that is, nearly impervious. Nevertheless, when these soils are affected by joint systems, as in the case here discussed, the fluids take advantage of these weaker surfaces and rise to ground level. It is therefore assumed that mud volcanoes correspond to the upper extremity of chimneys through which ground fluids associated with oil reservoirs are expelled (Deville and Prinzhofer, 2003).

Figure 4 - Natural Reserve of Salse di Nirano: cone-shaped mud volcano (photo by G. Tosatti)

The Nirano mud volcanoes (Municipality of Fiorano Modenese, Northern Apennines) – locally known as "salse" – are the most important and best developed pseudo-volcanic vents not only in the Emilia-Romagna region but in all of Italy; as such, they are protected as geosites of great scientific and educational importance. They are situated on the bottom of a wide, sub-circular depression – where the Plio-Pleistocene "Argille Grigio-azzurre" Formation crops out – at an altitude of 208 to 220 m a.s.l. Many mud erupting bodies of various sizes and shapes are found in the area. The caldera-like shape of this small valley may result from progressive ground subsidence owing to the continuous depletion of mud which, once ejected, flows into a stream below. Mud emissions vary in intensity, according to seasonal water availability. The arrangement of the vents along two contiguous alignments points to the existence of a considerable joint and fault system in the area (Bonazzi and Tosatti, 1999).

The Nirano mud volcanoes have always aroused great interest in travelers. They were first described by Pliny the Elder in his monumental work "Naturalis Historia", written around 60 AD, but only in the late 19th century was their real nature recognized, thanks to the careful observations of the famous naturalist, Abbot Antonio Stoppani (1876), who laid down a complete, and scientifically correct, description of the phenomenon, recognizing that these mud emissions are actually caused by liquid and gaseous hydrocarbons which come to the surface through ground discontinuities, pushing up salty water and mud.

At present, the Nirano mud volcanoes are found over a surface of about 55,000 m^2. Following the introduction of strict protection regulations, the geomorphologic situation of these mud volcanoes is in constant evolution, since, with the passing of time, new vents open and form new mud cones or pools, whereas others cease their activity.

The materials emitted by these vents are gases, liquids and solids. The gaseous phase, made up primarily of methane (87-96%) and, secondarily, of hydrogen sulphide, is the main conveyor of the liquid and solid components to the surface. The liquid phase is mainly constituted by surficial groundwater, although deeper water is sometimes mixed in. Occasionally the emission of water and fluid mud is accompanied by bituminous matter, clearly visible owing to the formation of concentric brown-blackish rings or iridescent films on the surface of the mud pools and craters. The solid phase is made up mainly of clayey materials dragged upwards by gases and water as they move through the Plio-Pleistocene argillaceous formation cropping out in the area. Variable amounts of mineral salts, such as sodium and potassium chlorides, which appear as very thin, whitish, powdery levels on the surface of the mud crust during

Figure 5 - Natural Reserve of Salse di Nirano: pool-shaped mud volcano (photo by G. Tosatti)

the hot, dry season, are found in the water.

Various types of clay materials are pushed upwards by the gas; in some cases they are the final transformation product of other minerals, which have been subject to prolonged leaching by the fluids characterizing each mud volcano. The minerals, identified via diffractometer analysis, are: illite (53%), smectite (14%), interlaminated i/sm (14%), chlorite (11%), and kaolinite (8%), whereas quartz and calcite are present in negligible amounts (Ferrari and Vianello, 1985). All the emission products of the mud volcanoes are definitely alkaline, their pH always exceeding 8.5.

In the past few years, measurements of helium and radon Rn-222 isotope present in the emission gases have been carried out in order to record possible correlations with local seismicity. In fact, the eruptive activity of the mud volcanoes of the northern Apennine margin seem to be influenced by seismic tremors. Observations carried out since 1986 on the Nirano mud volcanoes confirmed that the eruptive activity of these pseudo-volcanic bodies is actually influenced by the release of seismic energy from foci located in the mid-Apennine region at depths of about 4000-7000 m. In particular, radon anomaly peaks were recorded almost systematically from some hours to some days before and after the main seismic shock of medium-low intensity (3 to 4.5 magnitude) earthquakes (Gorgoni *et al*., 1988; Gorgoni, 2003).

The Nirano mud volcanoes are interesting also on account of the ecological changes induced by the deposition of sodium chloride. The herbaceous plants which colonize the clayey soil erupted by the mud cones are the best example of halophilous (i.e., "salt lover") vegetation in the province of Modena; they are usually found only along sea coasts.

Before the introduction of conservation regulations, human interference in this area was very evident, especially in regards to constraining the natural diffusion of the mud volcanoes. Indeed, for many years the mud cones were flattened in order to increase the surface available for farming. In addition, the most fluid mud was collected for therapeutic purposes. Finally, the area was also affected by the transit of sheep and goat flocks, which hindered the spontaneous growth of vegetation, especially in the mid-upper regions of the valley.

The Region's decree which in 1982 established the Natural Reserve of the Salse di Nirano, clearly states the aims of this protected area, which are: 1) to safeguard and preserve the natural (geomorphologic features, vegetation and wildlife) and environmental characteristics of the site; 2) to organize the territory for use according to scientific, cultural, educational, and recreational purposes; 3) to reconstruct the landscape unity of the whole area.

The considerable reduction of anthropogenic disturbances following the founding of the Reserve has allowed the eruptive phenomena to increase, so that they can now develop without constraints. Even the environmental conditions of the surrounding areas have now been upgraded, with a marked expansion of wild plants. In particular, the valley slopes, which were bare up to some twenty years ago, with gully erosion and badland morphology (Castaldini *et al*., 2003), and as attested to by various photographs of the time, are now subject to widespread growth of grass and shrubs, thus helping to confine the intense erosion processes typical of this low-Apennine belt, mainly made up of argillaceous formations. This fact, which is probably due to the abandoning of practices such as timber cutting and sheep farming, might demonstrate that the onset of badland morphology on these hills resulted not so much from climate changes but rather from deforestation and intense grazing (Tosatti, 2002).

DAY 2

(Modena – Rubiera – Scandiano – Albinea – Quattro Castella – Rossena and Rossenella – Canossa – Castelnovo ne' Monti – Pietra di Bismantova – Florence) Figure 6

The trip starts from Modena and heads to Scandiano, a large, picturesque village near the Tresinaro Stream, where the poet Matteo Maria Boiardo (1441-1494), author of the epic book "Orlando Innamorato", and the natural history scientists Antonio Vallisneri and Lazzaro Spallanzani, were born. Then proceed along the road at the foot of the hills towards Quattro Castella, a village dominated by the castle of Bianello, where a famous pageant is held every year to commemorate the coronation of Matilda di Canossa as "Vice-Regent" of Italy. The journey continues to San Polo d'Enza and Ciano-Canossa, quaint hamlets at the outlet of the Enza River into the plain. These villages are the starting points for the trip to the rugged cliffs of Rossena and Canossa. Running along the road from Montecavolo to Quattro Castella and San Polo, a series of terraces with yellowish-ocher paleosoils, belonging to the Riss-Würm interglacial, are visible. These terraces are some

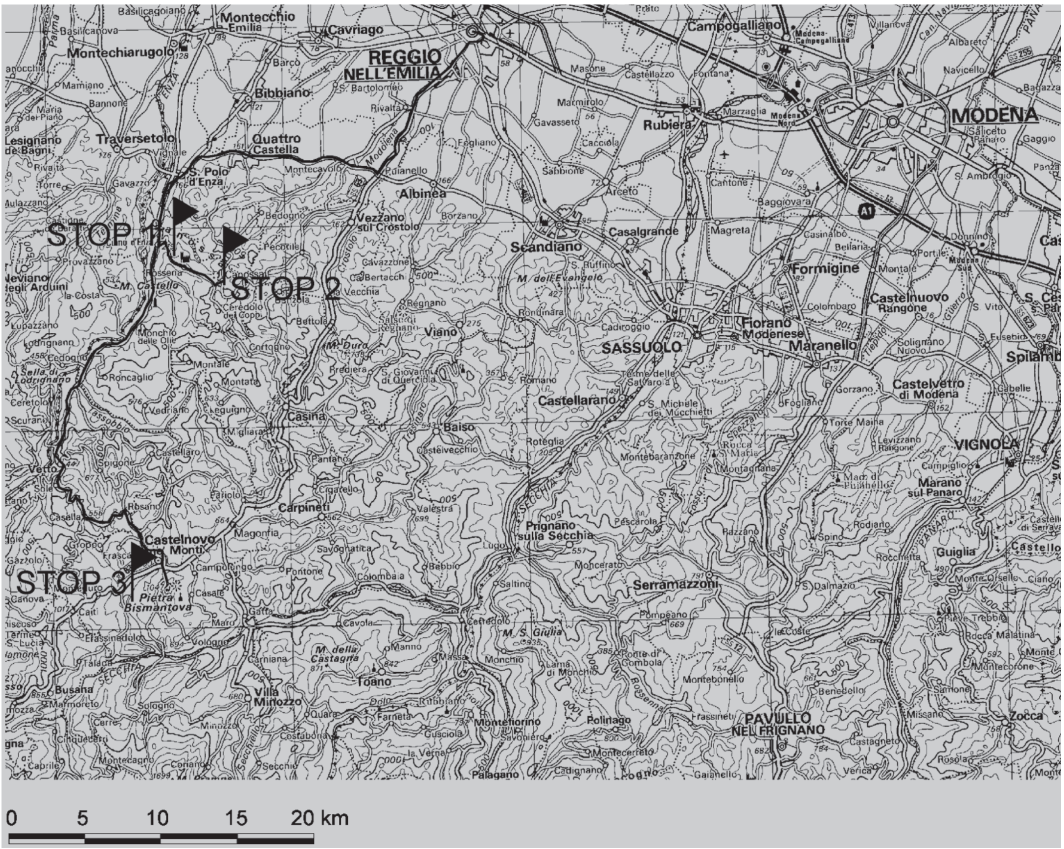


Figure 6 - Itinerary of the second day

15-20 m higher than the beds of the watercourses running through them. They are usually inclined by a few degrees towards the plain and rest on the first hill slopes, where their inclination abruptly increases up to 25°-30°, owing to the most recent neotectonic deformations they have undergone.

Once in Ciano — the seat of the Canossa Municipality — follow the road on the left leading to the Castle of Rossena. Soon the road winds up along hairpin turns among clayey hills for 5 km with an increase in altitude of about 300 m. Typically, the slopes are characterized by rillwash erosion, badlands and landslides, consequently farmland is very scarce, as in most clayey areas of this portion of the Apennines. Along the route excellent views are offered of Rossena with its ophiolites and Canossa with its underlying badlands. Unfortunately, the narrow, winding road does not allow stopping along this stretch for safety reasons. Visitors travelling on their own are advised to park their car and proceed on foot for short stretches. The photos they can take will be compensation for their effort.

Once in Rossena (**Stop 1**) head towards the castle along an easy path. This stronghold was built on a basalt cliff which, owing to selective morphology, stands out in the surrounding clayey landscape. From this outstanding landmark it is possible to admire the view of the Natural Reserve of the Campotrera ophiolites and the Enza valley. By following an easy trail on the right it is possible to observe the basalt outcrops in a small quarry under the tower of Rossenella.

After Rossena head towards Canossa (**Stop 2**), some 3-4 km away. Here the geologic panorama changes radically, even if the geomorphologic aspects seem to make the two localities seem uniform. The ruins of this historically important castle rest on a cliff which, in turn, lies on top of the Oligocene sequence. This stronghold, whose origin probably goes back

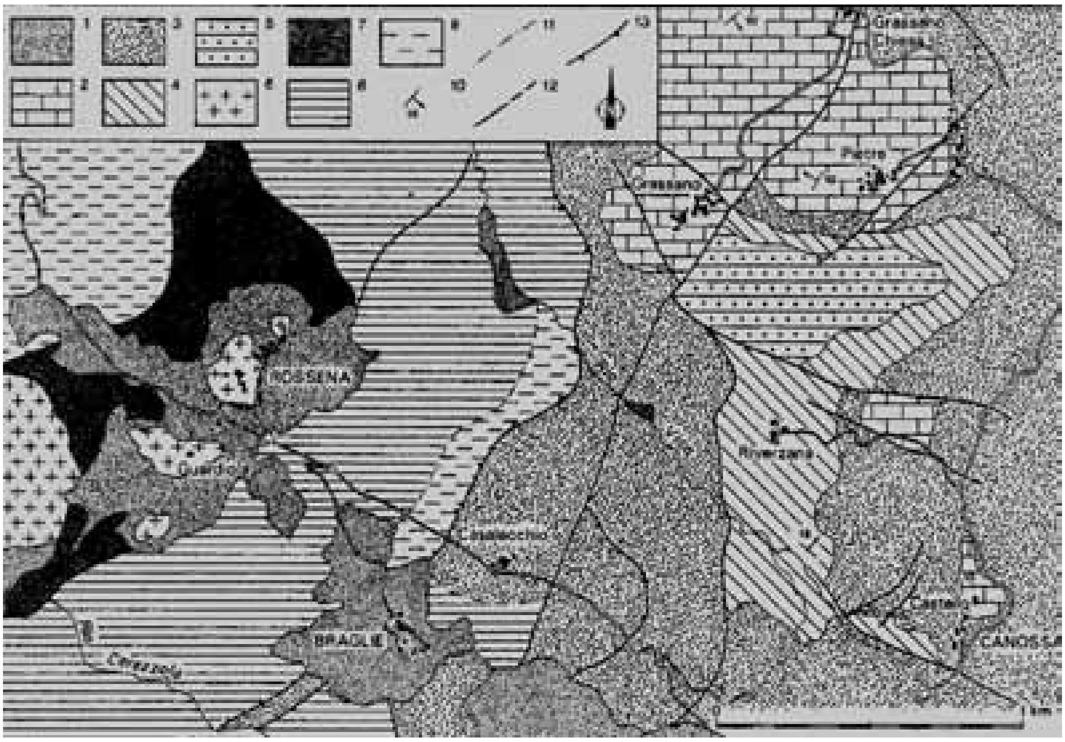


Figure 7 - Geologic sketch of the Rossena and Canossa surroundings. 1. Surficial Quaternary deposits; Epi-Ligurian Sequence: 2. Arenites from the Bismantova Group; 3. Canossa Olistostrome; 4. The Antognola Formation; 5. Ranzano Sandstone; 6. Rossena Ophiolites; 7. The Rossena Mélange; 8. Varicolored Shales; 9. Palombini Shales; 10. Dip of strata; 11. Uncertain boundary;12. Faults; 13. Overthrust (after Bortolotti, 1994)

to Longobard times, was enlarged and reinforced in the second half of the tenth century. The morphology of this calcarenite cliff, which can be considered an erosion relict, clearly results from selective processes on competent rocks overlying highly erodible clayey soils.
From Rossena go back to Ciano d'Enza, from where the state road on the right-hand side of the Enza River will take you as far as the village of Vetto, located on a sort of natural terrace over the Enza R., at the foot of Mt. Costa and Mt. Faille. From here proceed to Castelnovo ne' Monti, the largest village of the Reggio Emilia Apennines. Some 2.5 km from Castelnovo, the famous Pietra di Bismantova (**Stop 3**) is located. This is a large calcarenite slab (1047 m a.s.l.) in strong contrast with the surrounding mild hills.

The excursion ends in Florence, which is reached by following first the SS 63 state road towards Reggio Emilia and then, once in this town, taking the A1 motorway to the south.

The sites visited during this second day have been selected and scientifically defined as Geological Assets within the framework of an agreement made in 1999 between the Service for the Protection and Appraisal of the Landscape of the Emilia-Romagna Region and the Department of Earth Sciences of Modena and Reggio Emilia University (Bertacchini *et al.*, 2002a).

Stop 1:
The ophiolite cliffs of the Castle of Rossena and the Tower of Rossenella
Luigi Vernia

The cliffs of Rossena and Rossenella overlook the Enza Valley, situated inside the Natural Reserve of the Campotrera ophiolites in the Enza Valley. In this area seven ophiolite bodies of various sizes are found: they are nearly all made up of pillow basalts, whereas serpentines and gabbros are observable in two smaller

Figure 8 - Rossenella Tower (photo by P. Coratza)

outcrops. Fragments of granite rocks are associated with the basalts, as in other ophiolite outcrops of the Northern Apennines.

Broadly speaking, this belt of the lower Reggio Emilia Apennines, between the Enza and Secchia Rivers, is characterized by a rather simple geology, with the Tertiary meso-allochthonous formations of the "Epi-Ligurian Sequence" unconformably overlying the most widespread and well-known units of the "External Ligurian Domain", mainly the Mt. Cassio Unit and, to a lesser extent, the "Mt. Venere-Monghidoro Unit". The Ligurids are prevalently made up of Late Cretaceous rock types (Bettelli and De Nardo, 2001). The "Epi-Ligurian Sequence" belongs to a huge assemblage of sedimentary rocks known in the geologic literature as the "Vetto-Carpineti-Canossa Basin" sequence (Papani *et al*., 1989; De Nardo *et al*., 1991). This sequence shows an unconformable boundary with the "allochthonous" Ligurian bedrock. Epi-Ligurian sedimentation took place in a time interval spanning from the Mid-Late Eocene to the Middle Miocene, directly on top of a Ligurian substratum deformed by the tectonic displacements occurring during the various phases of Apennine orogenesis. For this reason this sequence is defined as "meso-allochthonous". In the low hills adjacent to the villages of San Polo and Quattro Castella (as well as in all of the Reggio Emilia foothill area), the Ligurian and Epi-Ligurian Units are overlain by the formations of the marine and continental sequence of the Po Valley margin, known also as the "Neoautochthonous" sequence. These formations were sedimented in the nearby Po Plain basin when the Apennine chain had nearly completely attained its present conformation, in a time interval of about 7 million years, from the late Miocene (Messinian) to the present. The tectonic boundary between Ligurian–Epi-Ligurian Units and neoautochthonous formations runs parallel to the structural axes of the Apennines, with a WNW-ESE trend, and is known as the "Gypsum Line", since along it the Messinian gypsum formation, which crops out extensively at Vezzano, Borzano and Mazzalasino, not far from Canossa, is often found.

The area surrounding Rossena is geologically composed of a dismembered "mélange" known as "Palombini Shales", where huge ophiolite masses crop out: they are themselves allochthonous bodies incorporated within a chaotic complex known in the geologic literature as the "Rossena Mélange". Unlike other adjacent areas, here the argillaceous matrix surrounding the ophiolites is represented not so much by the "Palombini Shales" but by the "Varicolored Shales". On the southern slope of the Campotrera cliff – which makes up the largest basalt outcrop of the area – the ophiolite bodies are incorporated in a gray-greenish argillaceous matrix with rare, dismembered reddish levels. The Varicolored Shale–Ophiolite set maintains a tectonic boundary with the previously mentioned Palombini Shales, corresponding to a NNE-SSW trending fault. The Varicolored Shales incorporating the ophiolites are themselves part of the Mt. Cassio Unit, which is considered the outermost unit of the External Ligurids (Figure 7).

Figure 9 - Rossena Castle (photo by P. Coratza)

In this area the best outcrop of pillow basalts is found in the small quarry underneath Guardiola di Rossenella, which can be easily reached following a trail off of the main road. Other good examples are visible along the path leading to the castle. The basalts cropping out in this area are characterized by "oceanic metamorphism", i.e. a low-temperature (max 300-400 °C), weak form of metamorphism which affected these rocks in the early stages of their formation. The process of deep mineralogical and geochemical changes of the original rocks caused by this oceanic metamorphism, is known as spilitization. During their effusion in the submarine environment, an interaction between basalt and sea water also occurred, with

Figure 10 - The Canossa cliff (photo by P. Coratza)

assimilation of sodium Na^+ by the adjacent rocks. This element, which substitutes calcium Ca^{++}, modified the minerals' chemical composition: the calcium extracted during spilitization was utilized to form secondary neoformation minerals such as calcite, prehenite, pumpellyite and, above all, rare datolite. These mineralogical phases which filled cavities and dykes, are of great scientific importance since they make up one of the most significant natural aspects of the Campotrera Natural Reserve, recently established by the Municipal Council of Canossa (Figure 8). A valuable booklet on the minerals of Campotrera and Rossena was published by the "Società Reggiana di Scienze Naturali" during a recent exhibition set up in Rossena Castle (Borghi *et al.*, 2002).

On top of the Rossena basalt cliff the massive castle of Matilda rises – perhaps the most beautiful and best preserved stronghold of that epoch. The cliff stands out on the surrounding clayey hills due to selective morphology. Rossena Castle – so called after the reddish color of its weathered basalt – is still inhabited, and now also houses a conference room used for meetings and cultural initiatives. This stronghold is probably contemporaneous to Canossa, therefore its original construction dates back to Longobard times. It was rebuilt by Bonifacius, the father of Matilda of Canossa, and was probably the best defense structure of Canossa itself, guarding the Enza Valley. Later Matilda donated it to the Church of Reggio, then it became property of the Pallavicini family and of Azzo da Correggio who gave hospitality to the poet Francesco Petrarch. After Azzo's time it passed through the hands of many different families, who carried out various renovations and alterations up to the present day. In the past ten years further improvements have been implemented. After so many changes, very little is left of the original building, but nowadays this stronghold can be regularly visited by the public. The annexed church of St. Matthew is from the XVIII century and of particular interest is also the small hamlet surrounding the castle (Figure 9).

Stop 2:

Calcarenite cliff of Canossa

Luigi Vernia

After Rossena head towards Canossa, some 3-4 km away. Here the geologic panorama changes radically, even if geomorphologic aspects make the two localities look uniform. In Canossa, in fact, the Epi-Ligurian Sequence is found, which is a meso-allochthonous Tertiary sedimentary sequence (Papani *et al.*, 1989; De Nardo *et al.*, 1991, Tellini and De Nardo, 1994; Vernia, 1994, Bettelli and De Nardo, 2001) deposited on top of the Ligurian Units during their tectonic displacement from SW to NE during Apennine orogenesis. The age of the entire sequence spans from the Middle Eocene to the Tortonian, according to certain authors, whereas others state it lasts up to the Messinian, including among the Epi-Ligurian Units also the Gypsum-Sulphurous Formation, that is, a time interval exceeding 30 Ma.

A good portion of this series of rock types – in particular the most recent part from the Oligo-Miocene

Figure 11 - The southwestern slope of the Pietra di Bismantova (photo by G. Tosatti)

– is visible in the badlands surrounding this site. The bottom of these badlands is made up of a light, marly-clayey, Late Oligocene formation called "Marne di Antognola", on top of which grayish polymictic argillaceous breccias, known as the "Canossa Olistostrome", are found. These sedimentary, matrix-supported breccias make up the Canossa badlands, which have been well-described in the international geologic literature. The Canossa Olistostrome is the result of submarine mud flows and debris flows which interrupted the sedimentation of the "Marne di Antognola" in the Late Oligocene. The polymictic breccias consist of grayish, sometimes varicolored, scaly clays, in which calcareous fragments and, more seldomly, reworked ophiolites are scattered in proportions and dimensions varying from place to place. This chaotic level attains a maximum thickness of about 150 m and is distributed along a belt some 40 km long stretching between the Modena and Parma Apennines. The Canossa Olistostrome is probably the result of several events, not just a single landslide, which have obviously reworked rocks from submarine ridges occupied by Ligurian Units such as the "Palombini Shales". This formation makes up most of the olistostrome which, to a lesser extent, is also made up of ophiolite breccias and "Varicolored Shales", which locally constitute the lower part of these polymictic breccias (Figure 7) .

The ruins of Canossa Castle rest on top of the cliff which, in turn, overlies the Oligocene sequence. Its morphology clearly corresponds to an erosion-selected remnant of competent rock types overlying deeply eroded clayshales. The Canossa cliff is in fact made up of calcarenites or whitish, well-stratified calcareous sandstones belonging to the Middle Miocene Bismantova Group and, in particular, to the outer shelf unit known as the "Pantano Formation".

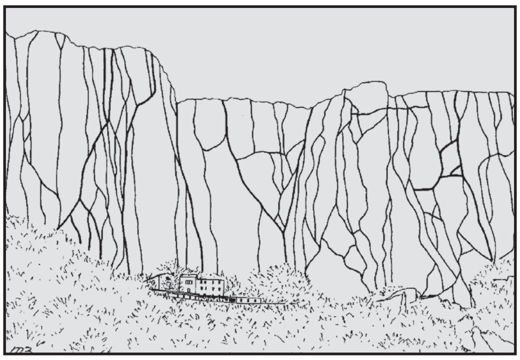


Figure 12 - Reconstruction of the main joints of the monastery trench (after Conti and Tosatti, 1994)

These calcarenites are widespread throughout the Reggio mid-Apennines, where they form the ridges of Mt. Tesa and Grassano, correlated to the rocks of the Canossa cliff, and crop out extensively near Casina, in the Tresinaro Valley and, in particular, at Mt. Valestra, where traces of ancient quarry activities can still be observed. In fact, these rocks have been used throughout the centuries, in particular during the Romanesque period, as building material. The top of the sequence is marked by the Contignaco Formation (cf. "Tripoli di Contignaco", *Auctt.*), a key horizon of silicified mudstones, thin bedded siliciclastic turbidites, and volcanoclastic sediments (Bettelli and De Nardo, 2001). It crops out in very thin bodies under the Canossa Castle and near Vetto and Carbognano, where it was spared from erosion by the presence of the Bismantova Group. The Epi-Ligurian Sequence terminates with the Bismantova Group, a very complex geologic assemblage made up of numerous formations and lithofacies.

Canossa Castle is a stronghold dating back to Longobard times (Figure 10). It was enlarged and reinforced in the second half of the 10th century by Sigifredo da Lucca and in 950, under the protection of Azzo Adalberto, it gave shelter to Adelaide, the young widow of Lotharius, who was escaping from Berengarius. Later, Adelaide married the Emperor Otto I and, when she died, was proclaimed a saint. Canossa became the military capital of the growing power of the Canossa dynasty; first with Todaldus, then Bonifacius and Countess Matilda. Here in Canossa the historical meeting between Pope Gregory VII and the Emperor Henry IV took place. After Matilda's death the castle was half demolished by the Guelphs from Reggio who were fighting against the Canossa Ghibellines. In the 15th century it was restored by the Este family; in 1502 it was governed by Ludovico Ariosto and, subsequently, was later the fief of several noble families who eventually abandoned it and let it fall into ruin.

The original name of Canossa was "Canusia" owing to the white-gray color of the rocks (*canus* means 'whitish' in Latin) – just as the adjacent stronghold of Rossena was so named after the reddish color of its oxidized basalts. When facing Canossa, one wonders whether the castle fell into ruin because of the progressive degrading of the rocky cliff following the advanced gully erosion of the underlying clayey breccias. One also wonders how much the landscape has changed in the last 1000 years, since the Emperor Henry IV remained kneeling in the snow for three days before being admitted to the presence of the Pope. It looks as if the space around the castle must have been considerably reduced during the last millennium, since in its present state the area would not accommodate the artisans' workshops, outhouses, stables and buildings housing the many servants and soldiers who must have made up the court of such an important castle in those days. Indeed, Canossa must have been a central place, isolated and nearly inaccessible owing to the morphologic characteristics of the site, where Countess Matilda found shelter during troubled times, whilst when the political situation was calmer, she preferred the easier and more comfortable site of Bianello. In addition, Canossa watches over a large portion of territory both in the mountains and over the upper plain and is visible from many corners of the Reggio Emilia Apennines. Therefore, this cliff must have had considerable strategic importance in those times. The most important sites of Matilda's territory are, in fact, located on the higher, more competent cliffs isolated by selective morphology from the more erodible clayey soils surrounding them.

Stop 3:

Morphologic and structural characteristics of the Pietra di Bismantova

Giovanni Tosatti

The Pietra di Bismantova is an intensely jointed calcarenite cliff belonging to the Epi-Ligurian Sequence of the Northern Apennines; it crops out along the watershed between the catchment basins of the Enza and Secchia Rivers (Province of Reggio Emilia).

The Pietra di Bismantova has a typical tabular shape, making it a unique morphologic feature in the Emilia Apennines. It attains a maximum elevation of 1046 m a.s.l. and, from its top, there is a magnificent view of the main Northern Apennine chain and the gypsum ridges of the upper Secchia River valley. This mountain relief is composed of a calcarenite, rhombohedral-shaped rocky slab with an arched appendix formed along its northern margin. It covers an area of about 185,000 m^2; along its entire perimeter there is a sheer drop with vertical cliffs and a maximum difference in altitude of 115 m (Figure 11).

The formations found in the area adjacent to the Pietra di Bismantova belong to the Ligurian thrust-nappe Units and the overlying Epi-Ligurian Units (Bettelli and De Nardo, 2001), here separated by tectonic boundaries. The former, extensively cropping out along the eastern margin of the slab, correspond essentially to the Argille Varicolori Formation (= polychromic clay shales of the Late Cretaceous-Early Eocene).

The Epi-Ligurian sequence is represented by the Ranzano (Late Eocene-Early Oligocene) and Antognola Formations (Late Oligocene-Early Miocene) and the Pantano Formation belonging to the Bismantova Group (Mid-Early Miocene). The latter, which makes up the Bismantova relief, is made up of massive arenaceous limestones, often showing cross-bedding, turning into properly stratified limestones towards the top (Conti and Tosatti, 1994).

From a morpho-structural viewpoint, the Pietra di Bismantova is an example of a *mesa*, whose summit corresponds to a lithologic-structural surface, which developed in different morphoclimatic conditions with respect to the present ones which are, on the contrary, characterized by a steady weathering regime (Bartolini and Peccerillo, 2002). In fact the whole area surrounding the Pietra di Bismantova has been affected by deep climatic changes from the end of the Würm glaciation to date, which led, at first, to the formation of extended *glacis*-type slope deposits and then the subsequent development of vast landslides (Gruppo di Studio Università Emiliane, 1976).

The longitudinal section of this slab (Figure 12) shows two central areas which have lowered along antithetic joints, thus forming wedge-shaped rocky masses. These features, typical of competent slabs overlying shaly clayey bedrocks, are designated in the literature as a “trench” (cf. Pasuto and Soldati, 1990). A fine example of a trench is visible along the cliff’s eastern face, just above an ancient monastery, flanked by a chapel, which dates back to the Early Middle Ages.

The morphologic depression located in the northernmost portion of the slab defines two clearly distinct parts. The southern one has a tabular shape (rectangular in plan view) and describes a mild syncline, with the axis directed towards the slab’s western margin. This part is mainly affected by two systems of subvertical joints: one with a N 220°-250° strike and the other with a N 130°-160° strike. Two other minor systems show orientations of about N 340°-350° and N 80°.

The slab’s arc-shaped portion, extending to the north of the main trench, is much more jointed and dismembered than the previous one, being subdivided into several loose blocks, progressively lower to the north, ending up in a heap of large boulders (NE extremity). All fractures present apertures that become very wide towards the eastern margin.

The differences between the arched and tabular portions are not constrained by the morphologic and structural factors alone, but primarily by the geologic characteristics of the bedrock underneath the Pietra di Bismantova. The arched and tabular portions of this cliff are, in fact, separated by a fault which displaces the boundary between the Epi-Ligurian Sequence and the polychromic clay shales formation. The latter make up the substratum underlying the slab’s arched portion, whereas the tabular part rests entirely on the more competent and thicker Epi-Ligurian Sequence of the Ranzano-Antognola formations.

The slope movements which affect the Pietra di Bismantova and surrounding areas are therefore deeply linked to its structural characteristics (joint systems, type and aperture of joints), as well as to the bedrock’s geomechanical properties. Landslides are definitely more active on the slab’s eastern margin rather than on the western one. The western slope of the tabular part, facing the village of Castelnovo ne’ Monti, is at present quite stable, although in the past it was affected by vast landslides, as witnessed by the presence of extensive slope deposits and dismembered boulders.

The situation of the slab’s southern margin is rather different, as it is more intensely jointed and affected by rock falls, in part still active. The higher landslide-proneness of this sector is due not only to the structural characteristics of the calcarenite slab but primarily to the presence of the polychromic clay shales cropping out along the final stretch of the road leading to the parking lot, where the paths leading respectively to the top of the cliff and to the old monastery and chapel start. The rock blocks fallen from the cliffs are further dragged down by a 2.5-km-long earth flow stretching nearly as far as the Secchia River. The morphologic evolution of this margin seems therefore linked primarily to the intense degradation of the slope’s lower portion where the polychromic clay shales crop out and give rise to the earth flow which, in turn, favors the detachment and fall of rock blocks.

The arched portion of the Pietra di Bismantova is mainly affected by earth slides/earth flows starting at the base of the rocky cliffs, at the boundary with the polychromic clay shales. These flows attain a length exceeding 1 km and are still active, as witnessed by the frequent cracks found on the walls of buildings in the underlying hamlets. Furthermore, this portion, which is now completely separated from the bigger part of the slab along the northern trench, is subdivided into various blocks, which become progressively lower towards NE. Unlike other situations of this kind, as with the San Leo slab in the Marecchia valley (central Italy) – where the peculiar arched shape was ascribable to structural causes linked to the tectonic stresses which affected the Epi-Ligurian Sequence following the movement and emplacement of the underlying Ligurian Units (Conti and Tosatti, 1993) – in this case the slab's arc-shaped appendix is a result of the formation of large rotational slides in the clay shales underlying the Bismantova calcarenites. These movements are accentuated along the eastern side owing to higher bedrock deformability, whereas the dismembered calcarenite blocks are subject to progressive lowering and tilting following lateral spreading and toppling processes.

Therefore, only along the arched part of the Pietra di Bismantova is the landslide evolution ascribable to deep-seated deformations of the bedrock, whereas in the other tabular parts rock falls and topples are predominant. These processes are further accentuated by meteoric weathering, mainly due to frost shattering and water percolation, as well as by higher erodibility and displacement of the underlying rock types.

References

Bartolini, C. and Peccerillo, A. (2002). I fattori geologici delle forme del rilievo. Cap. 5, 37-38, Pitagora Ed., Bologna.

Bertolini, G. and Pellegrini, M. (2001). The landslides of the Emilia Apennines (northern Italy) with reference to those which resumed activity in the 1994-1999 period and required Civil Protection interventions. *In* "Le frane della Regione Emilia-Romagna, oggetto di interventi di protezione civile nel periodo 1994-1999" (G. Bertolini, M. Pellegrini and G. Tosatti, Eds.), 27-74, *Quad. di Geol. Appl.*, 8(1).

Bertolini, G., Pellegrini, M. and Tosatti, G. (Eds.) (2001). "Le frane della Regione Emilia-Romagna, oggetto di interventi di protezione civile nel periodo 1994-1999". *Quad. di Geol. Appl.*, 8(1-2), 428 pp.

Bertacchini, M., Giusti, C., Marchetti, M., Panizza, M. and Pellegrini, M. (Eds.) (1999a). I Beni Geologici della Provincia di Modena. Artioli Editore, Modena, 104 pp.

Bertacchini, M., Giusti, C., Marchetti M. and Rossi, A. (1999b). I Sassi di Rocca Malatina. *In* "I Beni Geologici della Provincia di Modena" (M. Bertacchini, C. Giusti, M. Marchetti, M. Panizza, and M. Pellegrini, Eds.), 24-25, Artioli Editore, Modena.

Bertacchini, M., Coratza, P. and Piacente, S. (2002a). La Memoria della Terra, la Terra della Memoria. Censimento, Valutazione e Valorizzazione dei Beni Geologici in Emilia Romagna. Università degli Studi di Modena e Reggio Emilia – Regione Emilia-Romagna, Servizio Tutela del Paesaggio, CD-Rom.

Bertacchini, M., Coratza, P. and Piacente, S. (2002b). Paesaggi Culturali – Geologia e Letteratura nel Novecento in Emilia Romagna. Università degli Studi di Modena e Reggio Emilia – Regione Emilia-Romagna – Edizioni L'inchiostroblu, Bologna, 137 pp.

Bertacchini, M., Coratza, P. and Piacente, S. (2003). Le "Pietre del Diavolo" tra borghi e castelli nell'Appennino emiliano. Un percorso culturale nel paesaggio ofiolitico. *In* "La memoria della Terra, la terra della memoria" (S. Piacente and G. Poli, Eds.), 62-76. Università degli Studi di Modena e Reggio Emilia – Regione Emilia-Romagna – Edizioni L'inchiostroblu, Bologna.

Bettelli, G. and Bonazzi, U. (1979). La geologia del territorio di Guiglia e Zocca (Appennino modenese). *Mem. di Sc. Geol.*, 32.

Bettelli, G. and De Nardo, M.T. (2001). Geological outlines of the Emilia Apennines (Italy) and introduction to the rock units cropping out in the areas of the landslides reactivated in the 1994-1999 period. *Quad. Geol. Appl.*, 8(1), 1-26.

Bettelli, G. and Vannucchi, P. (2003). Structural style of the offscraped Ligurian oceanic sequences of the Northern Apennines: new hypothesis concerning the development of mélange block-in-matrix fabric. *Journ. Struct. Geology,* 25, 371-388.

Bettelli, G., Bonazzi, U., Fazzini, P. and Panini, F. (1989). Schema introduttivo alla geologia delle Epiliguridi dell'Appennino modenese e delle aree limitrofe. *Mem. Soc. Geol. It*., 39, 215-244.

Boccaletti, M., Decandia, F. A., Gasperi, G., Gelmini, R., Lazzaretto, A. and Zanzucchi, G. (1987). Carta Strutturale dell'Appennino settentrionale: Note Illustrative. C.N.R.-Prog. Fin. Geodin., publ. nr. 429, 203 pp.

Bonazzi, U. and Tosatti, G. (1999). Le Salse di Nirano. *In* "I Beni Geologici della Provincia di Modena" (M. Bertacchini, C. Giusti, M. Marchetti, M. Panizza, and M. Pellegrini, Eds.), 48-50, Artioli Ed., Modena.

Borghi, E., Patteri, P. and Scacchetti, M. (2002).

I minerali delle ofioliti di Campotrera e Rossena. Comune di Canossa, 47 pp.

Bortolotti, V. (1994). Appennino tosco-emiliano. 12 Itinerari. Guide Geologiche Regionali, Volume nr. 4, 2nd edition, Società Geologica Italiana, Rome.

Cancelli, A., Pellegrini, M. and Tosatti G. (1987). Alcuni esempi di deformazioni gravitative profonde di versante nell'Appennino settentrionale. *Mem. Soc. Geol. It.*, 39, 447-466.

Castaldini, D., Cosmin, C. and Ilies, D.C. (2003). Documenti digitali per la conoscenza integrata dei Geositi: l'esempio della Riserva Naturale delle Salse di Nirano. *In* "La Memoria della Terra la Terra della Memoria" (S. Piacente and G. Poli, Eds.), 121-127, Università di Modena e Reggio Emilia – Regione Emilia-Romagna, Edizioni L'inchiostroblu, Bologna.

Castellarin, A., Eva, C., Giglia, C. and Vai, G.B. (1985). Analisi strutturale del fronte appennino-padano. *Giornale di Geolologia*, 3rd series, 47, 47-76.

Conti, S. and Tosatti, G. (1993). Landslides affecting tabular rocks in complex geological situations: the case of Sasso di Simone and Simoncello (Northern Apennines, Italy). *In* "Landslides" (S. Novosad and P. Wagner, Eds.), 219-224, Proc. 7th ICFL, Prague and Bratislava.

Conti, S. and Tosatti, G. (1994). Caratteristiche geologico-strutturali della Pietra di Bismantova e fenomeni franosi connessi (Appennino reggiano). *Quad. di Geol. Appl.,* 1, 25-43.

De Nardo, M.T., Iaccarino, S., Martelli, L., Papani, G., Tellini, C., Torelli, L. and Vernia L. (1991). Osservazioni sull'evoluzione del bacino satellite epiligure Vetto-Carpineti-Canossa (Appennino Settentrionale). *Mem. Descr. Carta Geol. d'It.,* 46, 209-220.

Deville, É. and Prinzhofer, A. (2003). Vulcani di fango. *Le Scienze (Italian edition of Scientific American)* 421, 84-90.

Elter, P. (1973). Lineamenti tettonici ed evolutivi dell'Appennino settentrionale. *Acc. Naz. Lincei, Quad.* 183, 97-118.

Elter, P. (1994). Introduzione alla geologia dell'Appennino ligure-emiliano. *In* "Guide geologiche regionali – Appennino ligure-emiliano" (G. Zanzucchi, Ed.), 17-24, BE-MA Editrice, Milan.

Gorgoni, C. (2003). Le Salse di Nirano e gli altri vulcani di fango emiliani. I segreti di un fenomeno tra mito e realtà. Comune di Fiorano Modenese, Tipografia ABC, Sesto Fiorentino (Florence), 78 pp.

Gorgoni, C., Bonori, O., Lombardi, S., Martinelli, G. and Sighinolfi, G.P. (1988). Radon and helium anomalies in mud volcanoes from Northern Apennines (Italy) – a tool for earthquake prediction. *Geochemical Journal*, 22, 265-273.

Gruppo di Studio Università Emiliane per la Geomorfologia, (1976). Geomorfologia dell'area circostante la Pietra di Bismantova (Appennino reggiano). *Boll. Serv. Geol. d'Italia,* 97.

Labaume, P. (1992). Évolution tectonique et sedimentaire des fronts de chaîne sous-marins. Exemples des Apennins du nord, des Alpes françaises et de Sicile. Thèse de Doctorat, Université de Montpellier II, 470 pp.

Montanari, L. and Rossi, M. (1982). Evoluzione delle unità stratigrafico-strutturali terziarie del nordappennino: 1. L'Unità di Canetolo. *Boll. Soc. Geol. It.,* 101, 275-289.

Papani, G., Tellini, C., Torelli, L., Vernia, L. and Iaccarino, S. (1989). Nuovi dati stratigrafici e strutturali sulla Formazione di Bismantova nella "sinclinale" Vetto-Carpineti (Appennino Reggiano-Parmense). *Mem. Soc. Geol. It.*, 39, 245-275.

Pasuto, A. and Soldati, M. (1990). Rassegna bibliografica sulle Deformazioni Gravitative Profonde di Versante. *Il Quaternario* 3(2), 131-140.

Pellegrini, M. and Tosatti, G. (1992). Engineering geology, geotechnics and hydrogeology in environmental management: Northern Italian experiences. *In* "Geomechanics and Water Engineering in Environmental Management" (R.N. Chowdhury, Ed.), 407-428, Balkema, Rotterdam.

Piacente, S. (2003). Geositi nel paesaggio italiano: ricerca, valutazione e valorizzazione. Un progetto di ricerca per una nuova cultura geologica nell'ambito del Ministero dell'Università e della Ricerca (PRIN-COFIN 2001). *In* "La memoria della Terra, la terra della memoria" (S. Piacente and G. Poli, Eds.), 107-109, Università degli Studi di Modena e Reggio Emilia – Regione Emilia-Romagna – Edizioni L'inchiostroblu, Bologna.

Piacente, S. and Poli, G. (Eds.) (2003). La memoria della Terra, la terra della memoria. Università degli Studi di Modena e Reggio Emilia – Regione Emilia-Romagna – Edizioni L'inchiostroblu, Bologna, 159 pp.

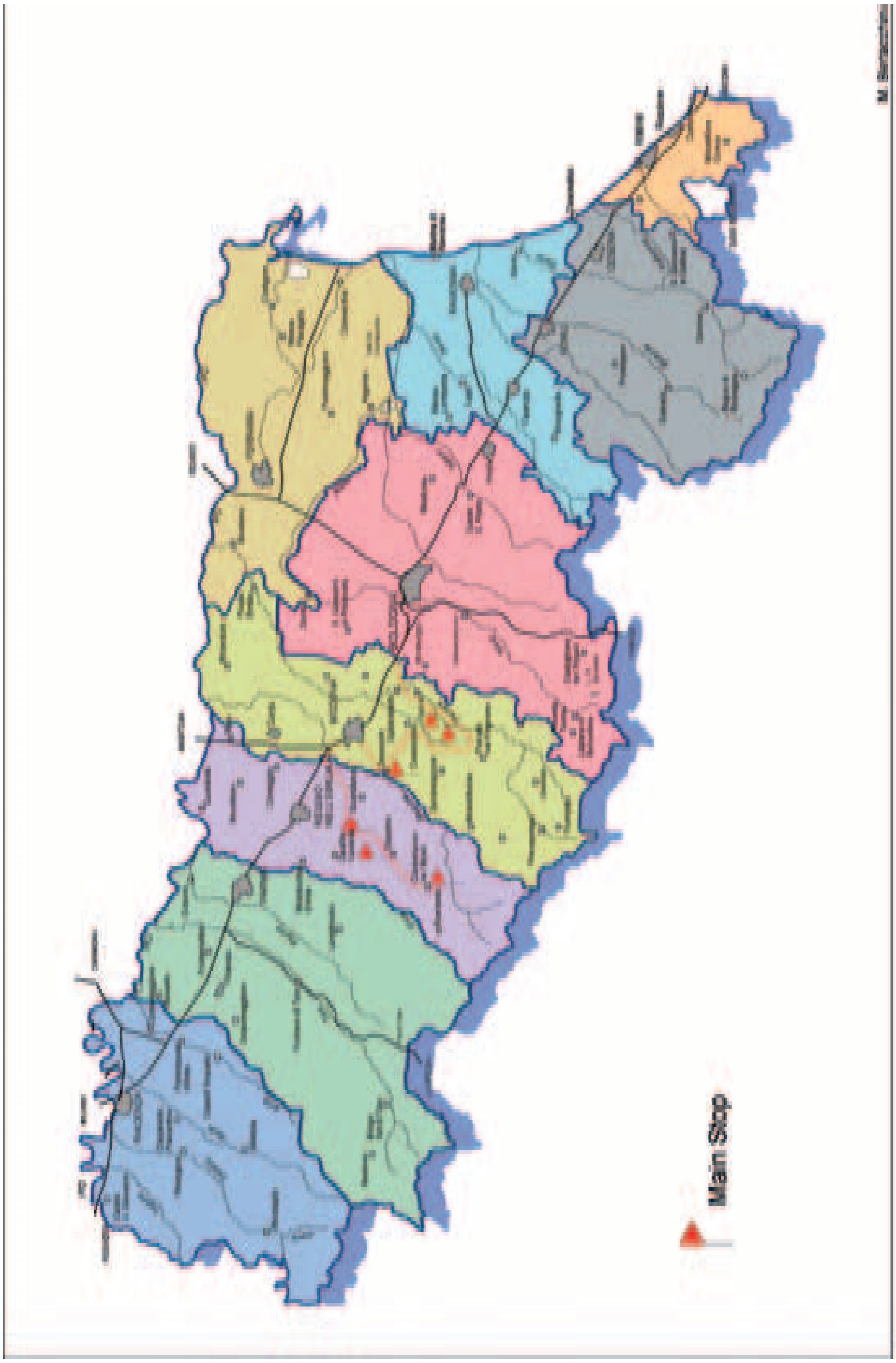
Piacente, S., Bertacchini, M., Coratza, P., Panizza, M. and Pellegrini, M. (2003). Geositi e Geomorfositi testimoni della Geodiversità in Emilia-Romagna. *In* "La memoria della Terra, la terra della memoria" (S. Piacente and G. Poli, Eds.), 49-61, Università degli Studi di Modena e Reggio Emilia – Regione Emilia-Romagna – Edizioni L'inchiostroblu, Bologna.

Pliny the Elder (~60 A.D.). Historia Mundi Naturalis. Book II, 85.
Principi, G. and Treves, B. (1984). Il sistema corso-appenninico come prisma d'accrezione. Riflessi sul problema generale del limite Alpi-Appennini. *Mem. Soc. Geol. It.,* 28, 549-576.
Ricci Lucchi, F. and Ori, G.G. (1985). Field excursion D: Syn-orogenic deposits of a migrating basin system in the NW Adriatic foreland: Examples from Emilia-Romagna region, Northern Apennines. *In* "International Symposium on Foreland Basins" (Ph. Allen, P. Homewood, and G. Williams, Eds.), 137-176, Fribourg, Switzerland, 2-4 September 1985, Excursion Guidebook.
Stoppani, A. (1876). Il Bel Paese. 2nd edition, Milan.
Tellini, C. and De Nardo, M.T. (1994). Carta geologica dell'Appennino Emiliano-Romagnolo 1: 10.000, sez. 218020 "Casola Canossa". Regione Emilia-Romagna, Servizio Cartografico, Ed. SELCA, Florence.
Tosatti, G. (2002). The Mud Volcanoes of Salse di Nirano. *In* "Geomorphological Sites: research, assessment and improvement" (P. Coratza and M. Marchetti, Eds.), 95-97, Workshop Proceedings, 19-22 June 2002, Modena.
Treves, B. (1984). Orogenic belts as accretionary prism: the example of the Northern Apennines. *Ofioliti* 9/3, 577-618.
Various Authors, (1991). Guida d'Italia. Emilia-Romagna. Touring Club Italiano, Milano.
Various Authors, (1992). "Le Case, le Pietre, le Storie. Itinerari nei Comuni della Provincia di Modena". Provincia di Modena, Grafiche Zanini Ed. 360 pp.
Vernia, L. (1994). Supergruppo del Trebbia e Itinerario nr. 1. *In* "Appennino tosco-emiliano. 12 Itinerari." (V. Bortolotti, Ed.), Guide Geologiche regionali*,* Volume nr. 4, Società Geologica Italiana, Rome.
Zanzucchi, G. (1963). La geologia dell'alta Val Parma. *Mem. Soc. Geol. It.* 4, 131-212.

Back Cover:
Road map of Emilia-Romagna region
marked by daily stops locations

FIELD TRIP MAP

32nd INTERNATIONAL GEOLOGICAL CONGRESS



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