

MAPS AND MULTIMEDIA TOOL FOR THE ENVIRONMENTAL TOURISM IN PROTECTED AREAS OF THE MODENA APENNINES (NORTHERN ITALY)

Doriano CASTALDINI

Università degli Studi di Modena e Reggio Emilia, Dipartimento di Scienze della Terra,
Largo S. Eufemia 19, Modena, Italy, e-mail: castaldini.doriano@unimore.it

Abstract: *Maps and Multimedia Tool for the Environmental Tourism in Protected Areas of the Modena Apennines (Northern Italy).* This paper describes the characteristics, criteria and methodology used for the implementation of maps (Tourist-Environmental Maps) and a multimedia tool (CD-Rom) for the environmental tourism in protected areas located in hilly and mountain areas of the Apennines of Modena. The hilly area is the Natural Reserve of Salse di Nirano; the “Salse” are small mud volcanoes formed by emissions of salt water mixed with mud and pushed up by methane rising to the surface along ground discontinuities. The mountain sectors consist of the upper Tagliole Valley and Mt. Cimone area, located within the Frignano Park; they are mainly characterized by glacial and cryogenic and gravitational landforms and deposits. Geomorphological maps and Digital Terrain Models (DTM) have been produced. Geo-tourist maps were derived from the geomorphological maps; the geo-tourist maps combine the most evident geological/geomorphological features with fundamental tourist information. The goal was to produce maps that could be easily interpreted by tourists to help them understand the landscape. The geo-tourist maps and the DTM are the cartographic documents characterising tourist-environmental maps which are thematic pocket foldable maps printed on both sides with illustration notes both in English and Italian. In addition, the tourist-environmental maps contain a synoptic description of the geological, geomorphological, botanical and zoological aspects, accompanied by photographs and information on excursion trails, visitor centers, behaviour rules, refuges and restaurants and, finally, cultural and tourist attractions in the protected and surrounding areas. The CD-Rom consists in a digital multimedia gallery, produced in the 2007 for 25th anniversary of the Reserve of Salse di Nirano, that can be browsed like a web page. The CD-Rom is structured in five main units. A brief introduction, with the guide to the CD-Rom, is followed by the description of the Reserve. The core of the CD-Rom is represented by the scientific aspects (description of geology, geomorphology, flora and vegetation, fauna, fossils and climate). The other parts are dedicated to the tourist aspects (with a Geo-tourist map) and to a multimedia gallery that groups sound recordings, movies, photos plus a virtual flight. The CD-Rom contain several thematic maps which can be downloaded as PDF files. The tourist-environmental maps and CD-Rom form part of the initiatives taken by Public Boards to improve the knowledge, utilisation and appraisal of the environment of protected areas in the tourist sector.

Key words: Environment, Geo-Tourist map, Digital Terrain Model, CD-Rom, Tourist-Environmental Map, Apennines of Modena, northern Italy

* * * * *

1. INTRODUCTION

This paper describes the characteristics, criteria and methodology used for the implementation of maps (Tourist-Environmental Maps) and a multimedia tool (CD-Rom) for the environmental tourism in protected areas located in hilly and mountain areas of the Apennines of Modena (northern Italy) (fig.1).



Figure 1. Location of the study areas: 1) Regional Natural Reserve of Salse di Nirano;
2) Upper Tagliole Valley and Mt. Cimone area in the Frignano Park.

The hilly protected area is located in the territory of Fiorano Modenese which is one of the main municipalities of the Modena Province; in ancient times it was called “the beautiful place”, due to its landscapes at the foothills of the Apennines. Its natural reserve named “Salse di Nirano” custodies the widest “salse” (mud volcanoes) complex of the

Emilia-Romagna Region and one of the most important in Italy and in Europe. The Salse di Nirano was the first natural reserve to be recognized by the Emilia-Romagna Region, in 1982, and among the first ones in Italy. In 2004, the European Commission identified the reserve area as a Site of Communitarian Importance.

Besides the peculiar geological phenomenon that has captured the interest of scientists since ancient times (Plinio the Elder was the first one) and keeps attracting tourists from all over Europe, this Natural Reserve represents an important ecosystem where it is possible to find and preserve habitats that are of primary importance at European level.

The mountain protected areas are the upper Tagliole Valley and the Mt. Cimone area; they are located in the Frignano Park (the term “Frignano” derived from the ancient pre-Roman people of “Liguri Friniati”), or Regional Park of the High Modena Apennines, which was established in 1988 by the Emilia-Romagna Region.

This Park safeguards a considerable portion of the Modena Apennines in the proximity of the Tuscan-Emilia watershed and stretches over 15,791 ha. The highest peaks of the Northern Apennines are found in this area such as Mt. Cimone (2,165 m a.s.l.), Mt. Giovo (1,991 m) and Mt. Rondinaio (1,964 m), Libro Aperto (1,936 m). The protected area is subdivided into zones with different levels of conservation (the actual Park covers about 9,000 ha and the so-called pre-Park about 6,000 ha) and is managed by a consortium of public boards whose administrative centre is in Pievepelago. The Park’s protected areas are located in the municipalities of Fanano, Sestola, Montecreto, Riolunato, Pievepelago, Fiumalbo and Frassinoro.

2. GEOGRAPHICAL, GEOLOGICAL AND GEOMORPHOLOGICAL SETTINGS

The Province of Modena is located in northern Italy in the Emilia-Romagna Region; the southern sector of its territory belongs to the Northern Apennines whereas the northern sector belongs to the Po Plain. The Apennine sector has an altitude ranging between about 150 m a.s.l. along its margin and about 2,000 m a.s.l. along the watershed between the Adriatic and Tyrrhenian sides of the Apennines; the highest peak is Mt. Cimone (2,165 m a.s.l.).

An account of the geographical, geological and geomorphological setting of the study areas follows.

2.1. Regional Natural Reserve of Salse di Nirano

The Regional Natural Reserve of Salse di Nirano is located in the Apennines of Modena margin (fig. 2). The “Salse” are emissions of salt water mixed with mud and pushed up by methane rising to the surface along tectonic discontinuities produced by the overthrusting of the Apennine chain front.

From a general viewpoint, among fluid venting structures, mud volcanoes are the most important phenomena related to natural seepage from the earth's surface (Mazurenko & Soloviev, 2003). Mud volcanoes have variable geometry and size, from one to two meters to several hundred meters in height, and are formed as a result of the emission of argillaceous material and fluids (water, brine, gas, oil). Although most mud volcanoes have a typical conical shape, they can assume a great variety of forms, referred to as “mud cones”, “mud lumps”, “mud diapirs”, “mud pies” etc., depending on their shape and size which, in turn, depend on the degree of mobilization initiated by pore-fluid pressures, frequency and characteristics of their activity, and viscosity of the outflowing mud (cf. Dimitrov, 2002 and references in it; Kopf, 2002). They occur globally in terrestrial and submarine geological settings: most terrestrial mud volcanoes are located in convergent plate margin with thick sedimentary sequences within active orogenic belts. Therefore mud volcanoes are known in many areas of the world; the most important ones are located in Azerbaijan, Mexico, Venezuela, Colombia, and Ecuador. In Europe they can be found in Italy, Albania and Romania (Deville & Prinzhofer, 2003).



Figure 2. Regional Natural Reserve of Salse di Nirano. Aerial view of the sub-circular shaped depression, at the bottom which the mud volcanoes (*salse*) are found. The “*calanchi*” (badlands) are also quite evident (Photo L. Callegari)



Figure 3. Cone-shaped mud volcanoes (Photo L. Callegari)



Figure 4. Pool-shaped mud volcano (Photo D. Castaldini)

The normal activity of mud volcanoes consists of gradual and progressive outflows of semi-liquid material called mud breccia or diapiric mélange. Explosive and paroxysmal activity are interpreted as responsible for ejecting mud, ash, and decimetric to metric clasts (Camerlenghi et al., 1992; Dimitrov, 2002). The occurrence of mud volcanoes is controlled by several factors, such as tectonic activity, sedimentary loading due to rapid sedimentation, the existence of thick, fine-grained plastic sediments and continuous hydrocarbon accumulation (Treves, 1985; Limonov et al., 1996).

Mud volcanoes in Italy occur along the external compressive margin of the Apennine chain (Pellegrini et al., 1982; Capozzi et al., 1994; Martinelli & Judd, 2004). They were described far back into history (Spallanzani 1795; Stoppani, 1873) and listed by Biasutti (1907) and Scicli (1972). Italian mud volcanoes are usually small when compared to other world examples. They rarely exhibit the periodic explosive activity (Capozzi & Picotti, 2002), which is often related to important seismic activity.

The Natural Reserve of Salse di Nirano covers an area of 207 ha and ranges in elevation from 140 m to 308 m a.s.l.; the extent of the area covered by the “Salse” is about 10 ha, in an altitude ranging between 200 m to 220 m a.s.l. It is therefore a lowhill territory, with a mean annual precipitation of about 800 mm and a mean annual temperature ranging between 12 and 13°C.

Since they are one of the most developed pseudo-volcanic phenomenon of the whole Italian territory, Salse di Nirano have always aroused great interest and were first described by Pliny The Elder, around 50 A.D., in his monumental work “Naturalis Historia”. Other scientists after him, especially in the 17th and 19th centuries, described the mud-volcano activity with the fantastic attributes of impressiveness and spectacularity (e.g. Ramazzini, 1698; Spallanzani, 1795). In particular, at the end of the 19th century the Abbot Stoppani described the “Salse di Nirano” comparing them to molehills out of which noises similar to “retching” came out; he gives them the epithet of “cesspool volcanoes” (Stoppani, 1873). Many other authors followed (e.g. Biasutti, 1907; Barbieri, 1947; Mucchi, 1966; Ferrari & Vianello, 1985; Bertacchini et al., 1999; Castaldini et al. 2003a; Gorgoni, 1998 and 2003).

In 1982, the Natural Reserve of Salse di Nirano was established in the area by the Emilia-Romagna Region with the aim of safeguarding and preserving the natural and environmental characteristics of the site.

More in detail, “Salse” (Italian for “salty”) are more or less muddy and saline springs, from which the names. Normally, bubbles of a variety of gasses are emitted, principally methane (95-98%), and sometimes also very small amounts of liquid hydrocarbons (oil), leading to the formation of stains or haloes. The shape of the ejection apparatus depends on the density of the muddy mixture: if it is dense, “cones” (single, double or multiple, called “gryphons”) of height ranging from a few decimeters to some meters may develop (fig. 3); if the muddy mixture is liquid, ground level “pools” (diameters ranging from a few decimeters to some meters) are formed (fig. 4).

The salinity of the water is always high but usually lower than that of seawater. Old brackish waters of marine derivation still impregnate deep underground rocks today, tending, however, to rise up to the surface (in the form of wet, plastic clayey bodies called “mud diapirs”) a little at a time along fractures and faults. The ascent of these mud bodies is determined by their density, lower than that of the surrounding (and overhanging) dry rocks, and favoured by the squeezing effect due to the huge weight of the latter, and the related pressure. The pushing upward action of the rising bubbles plays also a role in the ascent and final emission (in the form of flows, from a crater, during genuine eruptions) of the mud. Once at the surface, water evaporates and the mud dries, especially during summer; the dissolved salt tend then to form whitish patinas. When for various reasons the conduits are blocked near the surface, especially in the dry season, the features (and the cones in particular) become temporarily inactive. At a certain point, when the

resistance of the dry mud is overcome because of the overpressure caused by the progressive accumulation of methane, the gas again reaches the surface carrying up sludge and initiating a new stage of activity.

The number of vents can vary with time, as does their location: in the case of Nirano, the cartographic and photographic documents indicate a considerable stability during the last hundred years. A recent detailed survey has identified nearly forty (Gorgoni, 2003).

The salse are found on the floor of a sub-circular shaped depression, similar to a caldera (Fig.2). The depression is the result of a collapse in correspondence of a “mud-diapir” at the end of its uplifting activity (Castaldini et al. 2005c; Bonini, 2008).

Mud volcanoes are a classical example of “geomorphologic convergence”, that is, similar forms but with different origins (Panizza, 1992). In fact, although cone-shaped cones and flows are being formed and, in the specific case of Salse di Nirano, a caldera-like depression contains all these emissions, mud volcanoes have nothing to do with actual volcanism, although many visitors still think they have.

From a lithologic point of view, in the Natural Reserve of Salse di Nirano only marine silt-clay soil types (Plio-Pleistocene age) are exposed. The main streams are Rio Chianca, Rio delle *Salse* and Rio Serra. Some small ponds, marshy areas and swamp deposits are also found.

The main anthropogenic landforms include an abandoned quarrying area and an artificially flattened area corresponding to a disused farming area (a worm “farm” for anglers). Nearly everywhere it is possible to observe badlands (“*calanchi*”) in most cases stabilized by vegetation. The *calanchi* are one of the most spectacular landforms of erosion of the Apennine margin (fig. 2). They are typically composed of clayey soils and are characterised by a very fine drainage network and short, steep slopes with narrow interfluvies.

The deposits are mostly made up of very fine materials deposited by the main watercourses or by rill-wash on the slopes. Landslide bodies are quite common; they include small earth flows. Most landslide deposits have been colonized by vegetation which has contributed to stabilize them.

2.2. Areas located in the Frignano Park

The studied areas located in the Frignano Park are the upper Tagliole Valley and the Mt. Cimone. They are situated in the upper sector of the Modena Apennine, near the watershed, and are about 20 km far each from the other.

The climate is considerably influenced by the altitude and location near the watershed (Ferrari & Panizza, 1992; Servizio Meteorologico Regione Emilia-Romagna, 1995). Below 1,000 m a.s.l., the average annual temperature is about 10°C, whereas above this elevation, in the area around the watershed, it progressively decreases to 6°C. Annual precipitation ranges from 1,250 mm in the lower part to over 2,000 mm in the upper part. The annual mean values for the most rainy days range from 80 mm up to 125 mm and the ground is snow-covered for about 100 days a year.

The main geological units, continuously cropping out along the Apennines chain’s axis are the Tuscan Units, made up of Tertiary siliciclastic deep-water turbidites (Bettelli et al. 1989).

On the whole, the Northern Apennines are a NW-SE oriented mountain chain. In the study sector, though, the main ridge does not follow a linear trend but, in many places, the ridge is segmented and shifted to the east, along a series of reliefs aligned in the same direction.

The transversal section of the Apennine chain is asymmetrical, with a rather steep and rugged Tyrrhenian side, since it was modelled on dip-upstream strata, whereas the Adriatic one is much smoother and regular since it was shaped on dip-downstream strata.



Figure 5. North-western cirque of Mt. Giovo with a rock glacier found at the bottom. Reverse slopes in the upper part of the cirque are surface features of a rock slide which partially remodelled the edge of the cirque (Photo J. Valdati)



Figure 6. Panoramic view of Lake Turchino, Lake Turchino refuge and marsh at the bottom of the north-eastern cirque of Mt. Rondinaio (Photo J. Valdati)

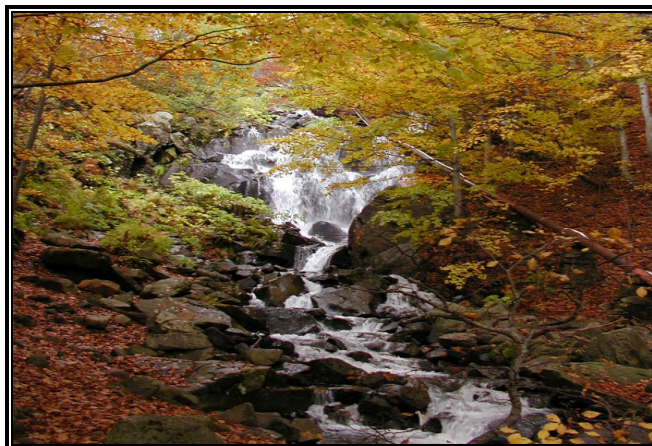


Figure 7. Waterfall of the Fosso del Lago Santo located downstream of the Lake Santo (Photo D. Castaldini)

The geomorphological studies in this sector of the Northern Apennines have mainly dealt with landforms linked to glacialism. The first investigations began at the end of the 19th century (e.g. De Stefani, 1887; Sacco, 1893; Pantanelli, 1886). In the first half of the 20th century many authors produced other mainly qualitative contributes (e.g. Desio 1927, Sestini 1936, Sacco 1941, Losacco 1948).

Losacco (1949b) proposed a new synthetic description of the Quaternary glaciations in the Northern Apennines. Some decades later, the same Author carried out an updated and well organised paper on the same topic (Losacco, 1982).

During the past decades, many Authors carried out several investigations on landforms in this sector of the northern Apennines. In particular, the features of the study areas were described by Carton & Panizza (1988), Ferrari & Panizza (1992), Jaurand (1999), Bertacchini et al. (1999), Castaldini et al. (2002), Castaldini et al. (2003b).

In this sector of the Northern Apennines the evidence of glacial traces is represented by both erosional (glacial cirques, overdeepened hollows, *roches moutonnées*) and depositional forms (moraines, moraine ridges), containing locally small lakes or impoundments.

Landforms resulting from periglacial processes (e.g. block fields, gelifluction deposits etc.) and from the action of surface running water (e.g., gullies, alluvial and colluvial fans, waterfalls etc.) are also quite common.

The most typical slope landforms, resulting from physical weathering of arenaceous rocks, are scree slopes and talus cones. The watershed areas are locally characterised by double ridges, trenches, concavities and reverse slopes which have been interpreted in some cases as the surface expression of "Deep-seated Gravitational Slope Deformations" and, in other cases, as rock slides.

Anthropogenetic landforms mainly linked to winter tourism, which has been particularly accentuated in the past decades, are rather widespread in Mt. Cimone area.

The Tagliole Valley is one of the most important valleys of the Apennines of Modena owing to the characteristics of the landscape. The main hamlets of the valley are Le Tagliole (1158 m a.s.l.), Ronchi (1146 m a.s.l.) and Rotari (1218 m a.s.l.). In this area winter tourism is not developed as much as in other areas of the Modena Apennines. The valley is frequented by excursionists, especially in the summer, owing also to the presence of several lakes.

The upper Tagliole Valley, elevations ranging from 1480 m a.s.l., to 1990 m. a.s.l., is mainly characterised by glacial and cryogenic landforms. The Macigno Formation, belonging to the Tuscan Units, is exposed in the upper Tagliole Valley. It is made up of sandstones with interbedded thin beds of pelitic sediments dipping northwards.

At the head of the valley are located the wide glacial cirques of Mt. Rondinaio (1964 m a.s.l.) and Mt. Giovo (1991 m a.s.l.)(fig. 5). The cirques have vertical faces which have undergone slope, cryogenic and running water processes. Their scarps are therefore covered with debris produced by various processes. The rock glacier found at the bottom of the cirque of Monte Giovo is of particular interest. At various altitudes, vast glacial deposits and numerous moraine ridges are found. Owing to the barrage of runoff waters, glacial landforms have determined the formation of the Lakes Torbido (1675 m a.s.l.), Turchino (1613 m a.s.l.)(fig.6), Baccio (1554 m a.s.l.) and Santo (1501 m a.s.l.), together with other small depressions which are now completely filled with swamp deposits. The running water processes have also formed gullies, gorges and waterfalls (fig. 7). Various glacial traces testify the presence of glaciers during the last glacial period (Würm) which ended about 10,000 years B.P. The considerable difference in height between the highest peaks and the valley floor (1,000-1,100 m) witnesses the high relief energy of the Tagliole Valley.

The Mt. Cimone area, elevations ranging from about 1300 m a.s.l., to 2165 m. a.s.l., is one of the most important winter tourism resorts of the entire Apennines. Along its slopes there are 50 km of ski pistes and numerous skilifts. Mt. Cimone (once named Mt. Alpone), with its altitude of 2165 m a.s.l., is the highest peak of the Northern Apennines.



Figure 8. Panoramic view of the eastern and northern slopes of Mt. Cimone (2165 m a.s.l.), the highest peak of the northern Apennines (photo D. Castaldini). The most part of the the forested area correspond to the body of a huge landslide in which the Lake della Ninfa is located (Fig.10) (Photo D. Castaldini)



Figure 9. Moraine deposits modelled in the shape of ridges on the south-eastern slope of Mt. Cimone (Photo D. Castaldini)



Figure 10. Lake della Ninfa (1,500 m a.s.l.), a very popular tourist resort of the Modena Apennines (Photo D. Castaldini)

With its typical pyramid-like shape, Mt. Cimone rises isolated and shifted to the north with respect to the Apennine watershed (fig. 8); it can be recognised from a distance of several km. The explanation of this situation lies in “geological causes”. The particular uplift of this mountain is in fact ascribable to the overthrust of an overturned outlier of Mt. Modino Sandstones, with the underlying Argille di Fiumalbo, on top of the Sequence of Mt. Cervarola Sandstones. The almost flat area at the northern foot of Mt. Cimone (Pian Cavallaro), has a structural origin since it corresponds to a contact surface between the two Units which was covered by moraine and waters deposits.

By examining the main features of the area, the eastern face of Mt. Cimone is characterised by a huge landslide deposit, with large arenaceous blocks (named the “Buca del Cimone” landslide), which took place in the post-glacial period. Moreover, at the present, it is not possible to establish whether the long ridge stretching NE of Mt. Cimone (Cresta di Gallo) was originally the rim of a cirque or not since others vast post-glacial slope movements have practically hidden the original morphology. Anyhow the presence of glaciers is witnessed by small cirques and well-recognisable moraine deposits modelled in the shape of ridges at the foot of the mountain (fig. 9). Many of the glacial forms could have been obliterated by erosional processes linked to the intense uplift occurring from the Middle-Upper Pleistocene to date.

Slope landforms and deposits due to gravity and, in particular, scree slopes and landslides are very common in this area. The landslides are of various types and, in some cases, have been controlled by tectonics. Worthy of note for its dimensions is the landslide immediately adjacent to Cresta di Gallo; inside its body the Lake della Ninfa, at an altitude of 1,500 m a.s.l., is found (fig. 10). This lake is a very popular tourist resort of the Modena Apennines. In the immediate surroundings of Lake della Ninfa, other genetically similar depressions are found; they are small impoundments seasonally fed by snowmelt. In addition, in the area of Mt. Cimone other small perennial or temporary lakes of various origin are found: they are structural (L. dei Bagni, 1,790 m a.s.l.), glacial (L. Il Terzo, 1,665 m a.s.l.), or artificial lakes used for the production of artificial snow (L. Le Polle, 1,326 m; L. Lamaccione, 1,495 m; dei Farsini 1,490 m; Piaggia Silvestro, 1,550 m a.s.l.).

Finally, among man’s activities which modified the landscape, the construction of large parking areas, refuges and ski pistes should be mentioned; these activities have mainly produced slope cuts.

3. TOURIST - ENVIRONMENTAL MAPS: CRITERIA AND METHODOLOGY

In this section the criteria and methodology used for the implementation of the tourist-environmental maps of the study areas are described. The methodology used for their implementation is represented in fig. 11.

These maps have been called “tourist–environmental” because, besides the most evident geological/geomorphological aspects and basic tourist information, they provide further information (such as information on the flora, vegetation and fauna) concerning the environment.

In the first step, in order to provide information about the physical landscape of each study area a Geomorphological map and a Digital Terrain Model (DTM) have been produced by means of GIS computer programme. The Regional Technical Map (CTR) of the Emilia-Romagna Region, at the 1:5,000 scale, was used as the topographic basis for their elaboration. Detailed morphological aspects are illustrated in a geomorphological map, produced from bibliographic research, analysis of aerial photographs and satellite images of various periods and field survey (fig. 12). In producing the geomorphological map of the study areas the legends used for recent geomorphological maps (for example Castaldini *et al.*, 1998; Pasuto *et al.*, 2005) were applied with some modifications.

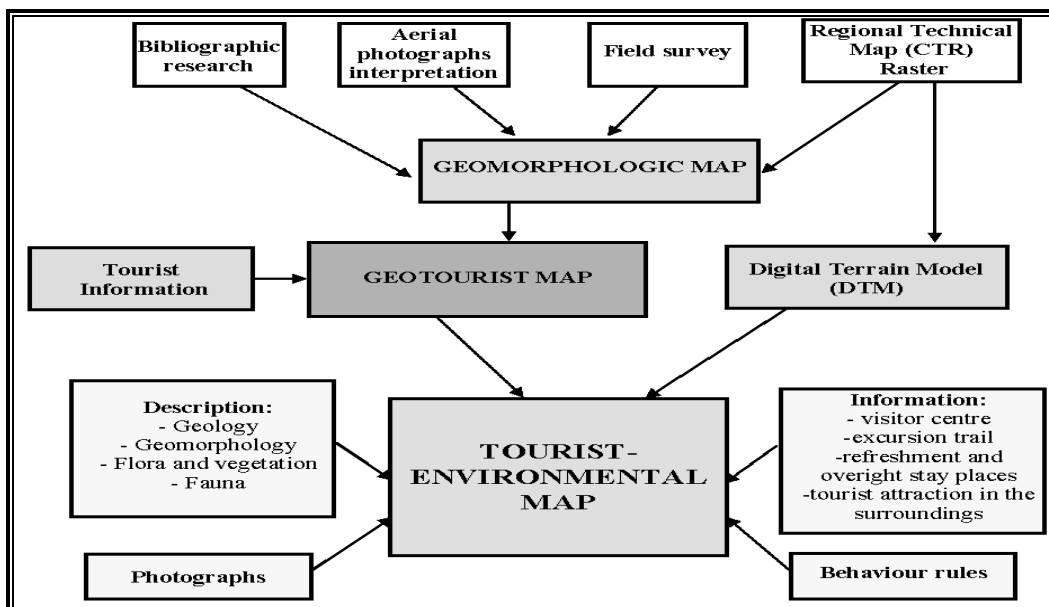


Figure 11. Scheme of the methodology for the implementation of the Tourist-Environmental Maps

The general morphological picture of each study area is effectively provided by the DTM on which the main tourist information have been located (e.g. footpaths, parking places, information points, lakes) (fig.13).

A geo-tourist map was derived from the geomorphological map, with appropriate simplifications and integrations. A Geo-tourist map can be considered as a thematic map. The latter are maps which focus on a particular aspect and, consequently, are aimed at specific users. First of all, in the preparation of a thematic map, the set of data that are going to be most utilised must be chosen, so that a language and mapping system are set up (Papotti, 2002). Therefore, a geo-tourist map combines the most evident geological/geomorphological aspects with basic tourist information (for example parking places, footpaths, picnic areas, overnight-stay places, etc...) (fig. 14). The aim was to produce maps that could be easily interpreted by tourists of average education to help them understand the landscape. In detail, the legend consists of two clearly distinct categories one with symbols representing the geological/geomorphological characteristics and a second showing symbols concerning to tourist information. Regarding the geological/geomorphological aspects, the Geo-Tourist map illustrates all the elements of the landscape that a tourist can observe and identify. An effort was made to use simple, clear and graphically pleasing symbols with short captions, avoiding specialized terminology (as it was used, for example, by Regione Emilia-Romagna, 2002; Angelini et al, 2004). In any case, the legend adopted is scientifically correct. From the practical viewpoint, using the geomorphological map as a starting point, the following criteria of elaboration were applied: i) the symbols of the main features were maintained (e.g., bedrock, hydrography, ridges, saddles); ii) the distinction of age and activity for landforms and deposits was eliminated; iii) faults/fractures were cancelled because they are not easily identifiable in the field; iv) the less representative forms and the most difficult to recognise were eliminated; v) the various types of deposits were simplified (e.g. single grouping for deposits of various origin); vi) the range of colours used was reduced.

The tourist information was mainly indicated with the commonly used colour (brown) and symbols for tourist maps.

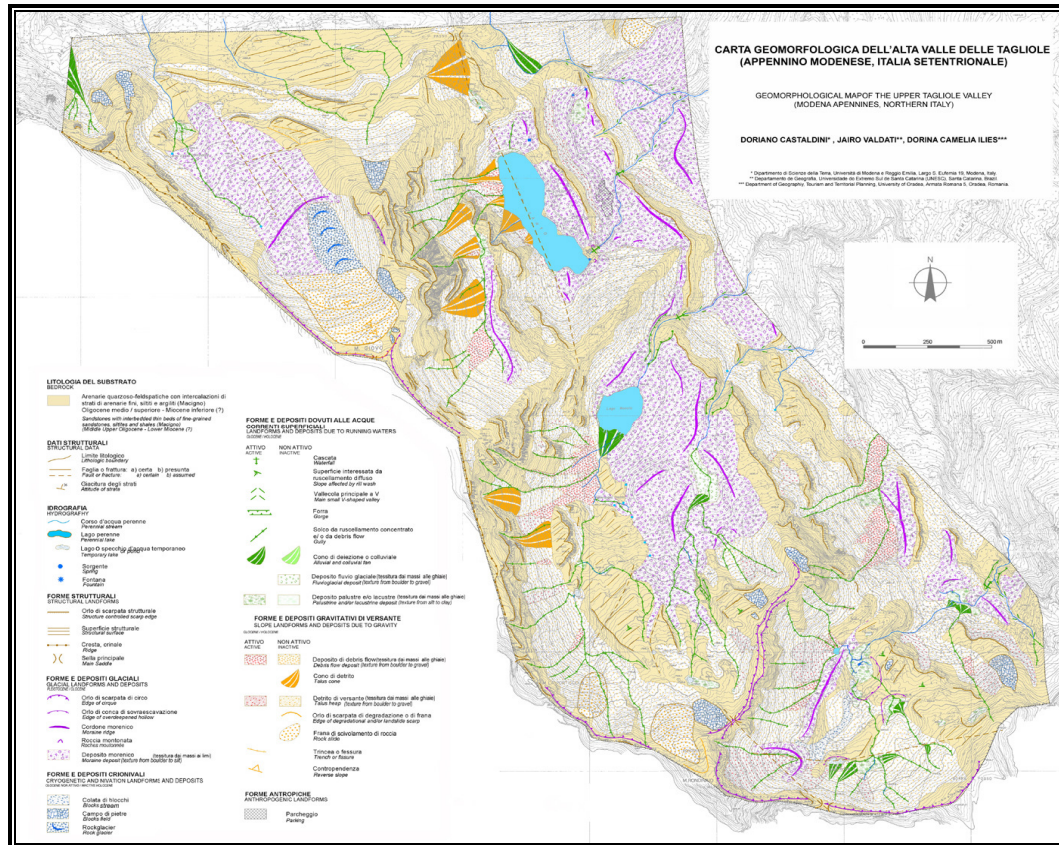


Figure 12. Geomorphological map of the upper Tagliole Valley (after Castaldini et al., in print)

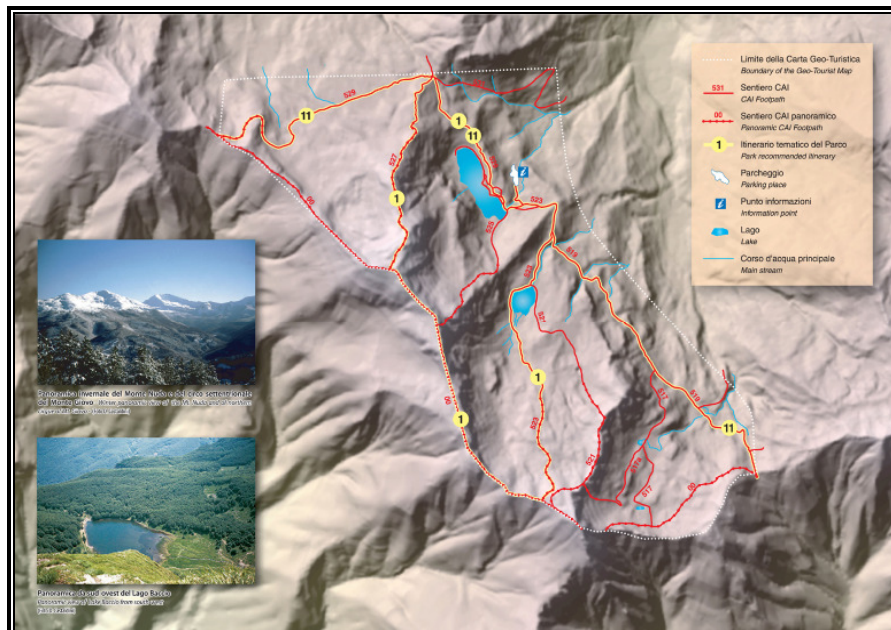


Figure 13. Digital Terrain Model of the upper Tagliole Valley (Castaldini et al., 2005b)

In the Geo-Tourist map and in the DTM the excursion trails are shown in order to facilitate the interpretation of the landscape and the elevation points for the tourist willing to walk along the trails suggested.

The geo-tourist maps and the DTM are the cartographic documents characterising Tourist-Environmental Maps.

4. TOURIST - ENVIRONMENTAL MAPS CHARACTERISTICS

In this section the main characteristics of the Tourist-Environmental Maps of the study areas are described. The Tourist-Environmental Maps are foldable, pocket-size, maps printed on both sides which the tourists can consult in the field while visiting the protected areas. These documents were produced in colour and in a easy to handle dimensions (48 cm x 63 cm). These are maps with illustration notes both in English and Italian. In addition, the Tourist-Environmental Maps contain a synoptic description of the geological, geomorphological, botanical and zoological aspects, accompanied by photographs and information on excursion foodpaths, visitor centres/information points, code of behaviour, refreshment points and overnight-stay places and, finally, cultural and tourism attractions in the protected and surrounding areas. Taking into account the use in the field of the maps, the descriptions contain concise information; the tourist who wishes to obtain more detailed information on the different topics can do so at home reading relevant books.

4.1. Regional Natural Reserve of Salse di Nirano

The tourist-environmental map of the Regional Natural Reserve of Salse di Nirano was printed with the financial support of the Municipality of Fiorano Modenese in the year 2004 (Barozzini et al., 2004) and has been described in Castaldini et al. (2005a).

The front side (fig. 15) contains the geo-tourist map of the Reserve and its description. Regarding the geological/geomorphological aspects, the geo-tourist map shows all the elements of the landscape that a tourist can observe and identify. In particular with regards to the mud volcanoes (“*Salse*”) – the main attraction of the Reserve – symbols graphically indicating both the “cone-shaped” forms and the “pool-shaped” formes have been used on the map so that the tourist can immediately locate them.

The tourist information include general information (e.g., Ca’ Tassi visitor center, excursion trails and panoramic points along them, picnic areas), wildlife information (bird-watching points) and logistic information (main access roads, parking places, refreshment and overnight-stay places).

The other contents on the front side of the tourist-environmental map include (besides the title, the list of the authors and the location of the Reserve): a short description of the excursion trails, the behaviour rules which the visitors should follow due to the high vulnerability of the mud-ejecting points and the services offered at the “Cà Tassi” visitor centre. In particular, “Cà Tassi” can receive visitors and school groups and, besides the possibility of hiking guides, one can find a naturalistic museum and library, the auditorium and multi-function room and shopping facilities.

The back side of the tourist-environmental map (Fig. 16) contains the DTM which provides the general morphological picture of the territory. By examining it, the presence of the sub-circular shaped depression, similar to a caldera, is quite evident even to non-experts. On the floor of this depression the “*Salse*” are found. Also the “*calanchi*” (badlands) are quite evident. The DTM clearly shows that these landforms are absent only in the southern part of the Reserve. Furthermore, the excursion trails have been indicated in order to provide the visitor with information on their elevation development.

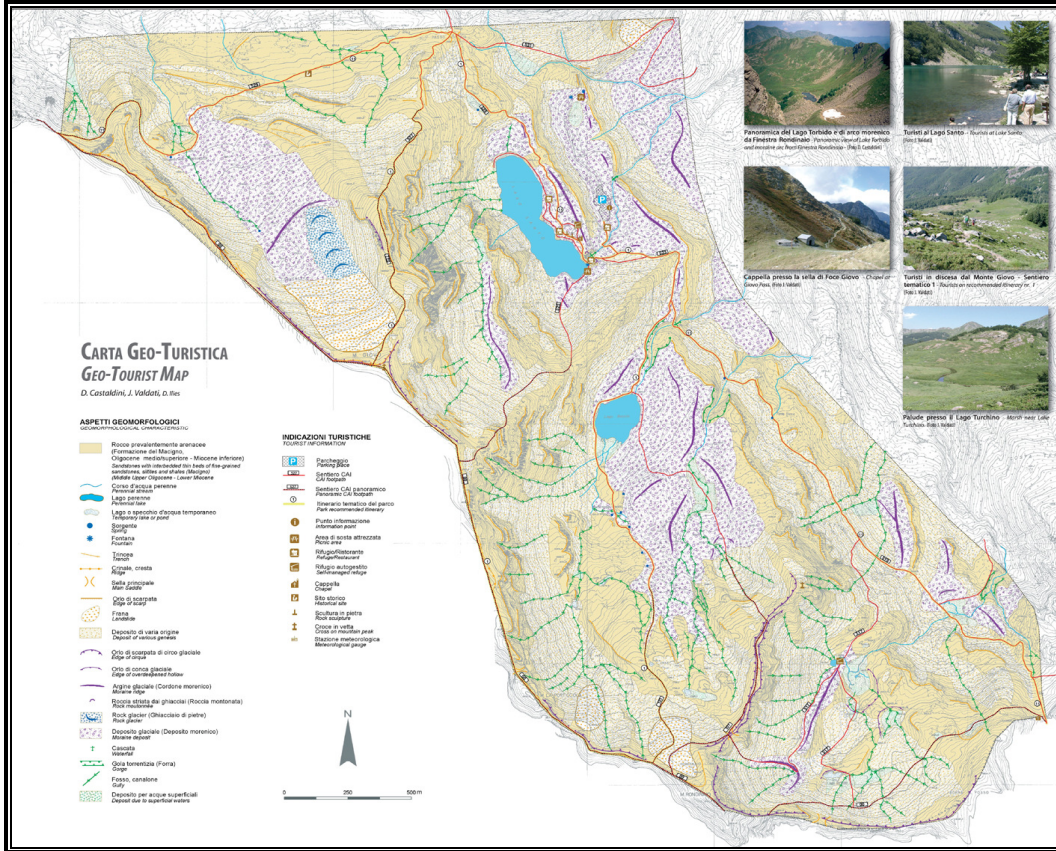


Figure 14. Geo-Tourist map of the upper Tagliole Valley (Castaldini et al., 2005b)

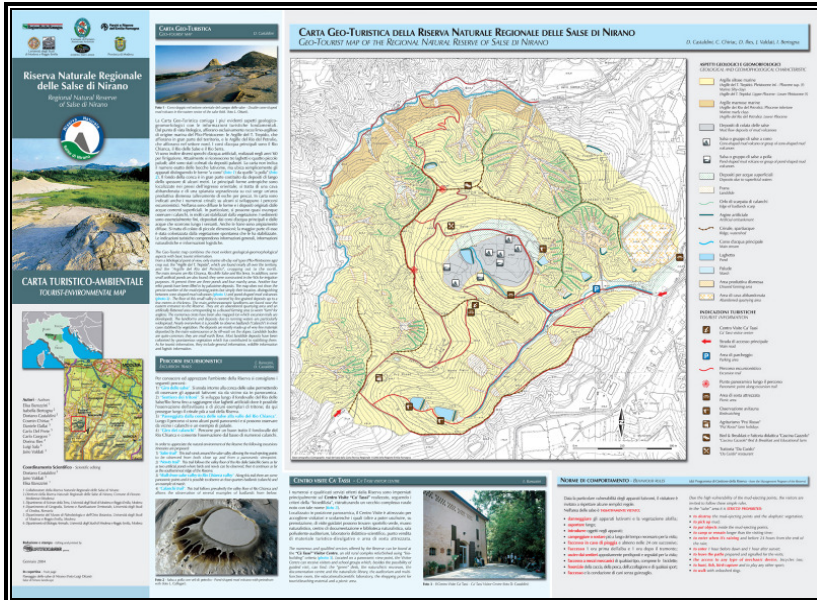


Figure 15. Front side of the tourist-environmental map of the Regional Natural Reserve of Salse di Nirano (Barozzini et al., 2004)



Figure 16. Back side of the tourist-environmental map of the Regional Natural Reserve of Salse di Nirano (Barozzini et al., 2004)



Figure 17. Tourists near Lago della Ninfa Refuge, located near the homonymous lake at the NE foot of the Mt. Cimone (Photo D. Castaldini)



Figure 18. Alpine marmot (*Marmota marmota*), a rodent which is very easy to observe in the high mountain meadows of the Mt. Cimone area (Photo A. Ilies)

The other contents on the back side of the tourist-environmental map include the description on the Reserve and *Salse* phenomenon (refer to section 2.1), information on the guided visit and the opening time of Cà Tassi visitor centre and on the refreshment and overnight stay places of the Reserve, description of the fauna, flora and vegetation and, finally, indication of the tourist attractions in the surrounding areas (the Sanctuary of the Virgin Mary in Fiorano, the Spezzano Castle, the Ferrari Cars Gallery in Maranello

and the spa in Salvarola Terme).

In detail, as for flora and vegetation, the *Salse* comprise a very particular environment because the saline mud and the physical characteristics of the clays favour the survival of only those vegetation species that can adapt to this type of environment. Those species, defined as *halophiles* (salt resistant) and *xerophiles* (tolerant to dry conditions), constitute a peculiarity within the flora community of the Salse di Nirano area. The most tolerant species to the saline conditions is the *Puccinellia borreri*, a graminaceous plant which lives near the craters abundantly during spring time (see fig. 3). The flora of the badlands is characterized by dense shrubs dominated by brooms which cover the slopes.

As concerns the animals, due to the limited extent of the Reserve, the fauna does not differ significantly from that of the surrounding hilly territory. Species living in areas characterised by stretches of cultivated and uncultivated fields, shrubs and small woods can be found, such as roe deer (*Capreolus capreolus*) and porcupine (*Hystrix cristata*). Among the birds, open areas are frequented by raptors such as the buzzard (*Buteo buteo*) and the kestrel (*Falco tinnunculus*).

4.2. Areas located in the Frignano Park

The tourist-environmental maps of the upper Tagliole Valley and Mt. Cimone area were printed with the financial support of the Frignano Park, respectively, in the years 2005 (Castaldini et al., 2005 b) and 2008 (Castaldini et al., 2008). The former one has been described in Castaldini et al., (2005a). The two maps, whose structure is quite similar to that of the Natural Reserve of Salse di Nirano, present some small differences between them as the Mt. Cimone studied area is wider than of the upper Tagliole Valley.

Anyhow, the main element of the front side of the maps is the geo-tourist map. Regarding the geological/geomorphological aspects, the geo-tourist maps illustrates, with simple, clear, graphically pleasing symbols and short captions, the main features of the landscape which have been described in section 2.2 (e.g. lakes, gullies, landslides, deposits of various genesis, glacial cirques and deposits etc...). As for the tourist information, the maps includes logistic information, such as parking places, picnic areas, refuges/restaurants, as well as general information such as Italian Alpine Club (CAI), footpaths, Park recommended itineraries, chapels, historical and cultural artefacts, meteorological stations. In the geo-tourist map of Mt. Cimone area, ski pistes and ski lifts are also indicated.

In both areas, most of the tourist facilities are easy to reach from the parking places. In the upper Tagliole Valley the tourist facilities are concentrated near Lake Santo, while in the Mt. Cimone area they are distributed in five zones all around the mountain (fig.17).

The other contents on the front side of the tourist-environmental maps include (besides the title, the list of the authors and the location of the areas), short notes on visitor centres, where tourist information on the Frignano Park are available, and on the Park recommended itineraries.

The back side of the tourist-environmental maps include the DTM on which the CAI footpaths, Park recommended itineraries, lakes and main streams are indicated.

The other contents on the back side include the illustration of the Frignano Park, the description of the tourist attractions in the surroundings, which include several villages with picturesque centres, and the description of fauna, flora and vegetation.

As concern flora and vegetation, the arboreal vegetation situated at an altitude above 1000 m a.s.l., is characterised by deciduous broad-leaf mesophyll woods with beech trees (*Fagus sylvatica*) and white fir trees (*Abies alba*), associated with other mixed broad-leaf species, mainly found at lower altitudes. At higher altitudes, beyond the treeline, the woods give way to meadows and scattered shrubs with a widespread

dominance of bilberry (*Vaccinium myrtillus*) and cranberry (*Vaccinium gaultherioides*) shrubs. Wetland environments, consisting of ponds, temporary marshes, peat bogs, springs and streams, are populated by species such as *Eriophorum scheuchzeri* and *Swertia perennis*.

As concern the description of fauna, generally speaking, the animal species commonly found in woods and high mountain meadows of the Northern Apennines are present, although the widespread presence of glacial landforms allows a higher concentration of species typical of rocky habitats and wetlands. The Black redstart (*Phoenicurus ochrurus*), the Northern wheatear (*Oenanthe oenanthe*) and the Water pipit (*Anthus spinoletta*) are commonly found in high mountain meadows. Among the most typical mammals of this habitat, the Snow vole (*Chionomys nivalis*) is worthy of note. The small rodents are the favourite prey of the European asp (*Vipera aspis*), a rather rare reptile, and of the bird raptors such as the kestrel (*Falco tinnunculus*) and the Golden eagle (*Aquila chrysaetos*). In the high mountain meadows of the Mt. Cimone area it is very easy to observe the Alpine marmot (*Marmota marmota*), a rodent which has been introduced from the Alps about 40 years ago (fig. 18). The numerous wetland places host the European common frog (*Rana temporaria*), the Italian Alpine newt (*Triturus alpestris apuanus*) and the European common toad (*Bufo bufo*). Various ichthyic species have been introduced in some lakes, where they live together with the Brown trout (*Salmo trutta*), which is the only autochthonous species of these areas.

5. MULTIMEDIA TOOL

The year 2007 was the 25th anniversary of the Regional Reserve of Salse di Nirano and, for that occasion, the Municipality of Fiorano, besides the organization of a workshop open to the public and to the international scientific community, has financed the production of a digital multimedia gallery, in a CD-Rom format, to a team composed by botanists, palaeontologists, zoologists, climatologists, geomorphologists and geologists from the University of Modena and Reggio Emilia (Castaldini et al., 2007).

The aim of the CD-Rom was to increase the value and the popularity of the Natural Reserve of the Salse through detailed scientific studies undertaken on all naturalistic and anthropic aspects of the Reserve. The output of the work was a renewed and up-to-date research organized in one CD-Rom that can be browsed like a web page.

The CD-Rom is structured in five main units, which can be reached by means of the navigation menu on the left of the page; the first chapter is called "Home" (Fig. 19) and contains an introduction page, a guide to the CD-Rom, a well structured and easy-to-use site map and the pages of the local political organisations, such as the Comune di Fiorano Modenese, the Provincia di Modena and the Regione Emilia-Romagna, and the page of the University of Modena e Reggio Emilia.

Object of the second chapter, called "Reserve", is the Natural Reserve itself, with its history from its establishment to year 2007, its visitor centre, its services.

The third chapter, called "Scientific Aspects", deals with all scientific aspects of the reserve: geology and mud volcanoes phenomenon (pages are realized in grey), climate (in light blue), geomorphology (in brown, with year-1973 and -2007 geomorphological maps), fossils (yellow), flora and vegetation (green, with year-1973 and -2006 state-of-vegetation maps)(Fig. and fauna (ochre). Each scientific chapter is an autonomous page; words that are too specific of each scientific jargon have been left as they are in the text, but an hyperlink on them may guide the reader to better understand their meaning thanks to pop-up windows. In this manner, the non specialist may acquire a deeper culture on the scientific aspects of the Reserve and of the natural sciences in general.

The fourth chapter (completely realized in light green), called "Tourist Aspects", provides all tourist information about the Reserve and the surroundings, such as local

points of interest, accommodation opportunities and the Geo-Tourist Map of the Reserve (derived from a simplified geomorphological map with tourist information added and updated at year 2007) which is the core of this section. This map, like all the other maps present in the CD-Rom, can be also viewed and downloaded as PDF file in order to allow the reader to reach the maximum detail or to print the map and use it when visiting the Reserve.

The fifth chapter, called "Multimedia Gallery", contains wide collections of pictures, audio tracks (mp3 format), videos (mpg format) and scientific researches (pdf format), a bibliographical gallery, containing references and PDF files of the main scientific papers on the Reserve area, a list of useful links and a virtual flight, made using a DTM and colour orthophotographs, that gives an overview over the territory of the Reserve.

Each chapter contains different pages; each page consists of three "columns": the left column contains the navigation menu, which allows the user to enter the different thematic chapters and navigate to the single pages; the central column contains text and pictures. Some words, called links, are white; if the user rolls with the cursor over them, they turn orange; it is possible to click them: they establish connections between the different pages; the right column contains so called roll-over pictures: they have the same function as links, in fact they turn coloured as soon as a link is activated, or as the user rolls with the cursor on them.

Click on its title, or on the corresponding symbol on its left, to display a multimedia file; if correctly installed, multimedia players open automatically.

Each page is provided with arrow commands, which allow the user to go to the top of the page or jump back to the last visited page.

The whole CD content has been translated in English: click the small flag on the top right corner of the page to enter the English version (a long abstract of the Italian version), and the corresponding Italian flag to switch to the Italian version.

The most part of the CD content has been utilized to implement the new web site of the Natural Reserve of Salse di Nirano: <http://www.fiorano.it/Turismo/Salse%20Nirano/index.htm>

6. CONCLUSIONS

The tourist-environmental maps and the CD- Rom described in this paper are part of the initiatives taken by public Boards (a Local Administration and a Park of the Emilia Romagna Region) for improving the knowledge, utilisation and appraisal of the environment of protected areas in the tourist sector. These materials were also produced to meet the ever-growing educational needs of public boards and to contribute to transfer of information from scientific research to possible users and local communities. It should be also highlighted that the "Recommendation Rec (2004) 3 of the Council of Europe on conservation of geological heritage and areas of special geological interest" underline the importance of the Earth Heritage and Geodiversity and the tools to create opportunities for education, recreation and tourism (Panizza, 2005).

The Geo-tourist maps, found in the tourist-environmental maps as well as in the CD-Rom, are documents within the framework of geomorphological studies. The aim was to produce maps that could be easily interpreted by tourists with an average education and help them to understand the surrounding landscape.

The text of the different topics described in the tourist-environmental maps and in the CD-Rom has been implemented by University experts with the collaboration of representatives of the protected areas. Therefore it should be emphasized that this work was proposed and produced thanks to the aggregation of University researchers with the cooperation of public Boards.

The tourist-environmental maps and the CD-Rom are sold at Visitor Centres and at information points within the protected areas.

Acknowledgments

The studies are within the framework of the IAG Geomorphosites Working Group (coordinator Prof. Manuel Reynard) activities and FAR Project Research of the Earth Science Department and in cooperation with the local public administrations (Municipality of Fiorano Modenese and Frignano Park).

Many thanks to the colleagues who have collaborated in different ways to the implementation of the three Tourist- Environmental maps and of the CD-Rom (see references).

REFERENCES

- Angelini, S., Farabollini, P., Menotti, R.M., Millesimi, F., Petitta, M., (2004), *Carta Geomorfologico-Turistica del comprensorio dei monti retini (Appennino Centrale). Scala 1: 12.500*, Litografia Artistica Cartografica S.r.l., Firenze.
- Barbieri, G., (1947), *Nuove osservazioni sulle salse emiliane*, Riv. Geogr. It., 54.
- Barozzini, E., Bertogna, I., Castaldini D., Dallai D., Del Prete C., Chiriac C., Gorgoni C., Ilies D.C., Sala L. and Valdati J., (2004), *Riserva Naturale Regionale delle Salse di Nirano”: Carta Turistico- Ambientale*, Comune di Fiorano-Assessorato Ambiente. Eliofofotecnica Barbieri, Parma.
- Bertacchini, M., Giusti, C., Marchetti, M., Panizza, M., Pellegrini, M., (eds.), (1999), *I Beni Geologici della Provincia di Modena*, Artioli Ed., Modena, 104 pp.
- Bettelli, G., Bonazzi, U., Fazzini, P., Gasperi, G., Gelmini, R., Panini, F., (1989), *Nota illustrativa alla carta geologica schematica dell'Appennino modenese e delle aree limitrofe*, Mem. Soc. Geol. It., 39, 487-498.
- Biasutti, R., (1907), *Le salse dell'Appennino settentrionale*. Mem. Geogr. 2, pubbl. suppl. Riv. Geogr. It.
- Bonini, M., (2008), *Elliptical mud volcano caldera as stress indicator in an active compressional setting (Nirano, Pede-Appennine margin, northern Italy)*. Geology, 36, 2, p. 131-134
- Camerlenghi, A., Cita, M. B., Hieke, W., Ricchiuto, T., (1992), *Geological evidence for mud diapirism on the Mediterranean Ridge accretionary complex*. Earth and Planetary Science Letters 109, 493-504.
- Capozzi, R., Picotti, V., (2002), *Fluid migration and origin of a mud volcano in the Northern Apennines (Italy): The role of deeply rooted normal faults*, Terra Nova 14, 363-370.
- Capozzi, R., Menato, V., Rabbi, E., (1994), *Manifestazioni superficiali di fluidi ed evoluzione tettonica recente del margine Appenninico Emiliano-Romagnolo: indagine preliminare*, Atti Tic., Sci. Terra, 1, 247-254.
- Carton, A., Panizza M., (a cura di) (1988), *Il paesaggio fisico dell'Alto Appennino emiliano*. Grafis Ed. 182 pp.
- Castaldini, D., Caredio, F., Pulcinelli, A., (1998), *Geomorfologica delle valli del Rio delle Pozze e del Torrente Motte (Abetone, Appennino Tosco-Emiliano)*. Geogr. Fis. Dinam. Quat. 21, 177-204, Torino.
- Castaldini, D., Coratza, Paola, Iotti, M., (2002), *The lakes of the high Emilia-Romagna Apennines (northern Italy): a preliminary review of their geomorphological characteristics*, Analele Universitatii din Oradea, Seria Geografie, Tom XII, 19-29.
- Castaldini, D., Chiriac, C., Ilies, D. C., con la collaborazione di Barozzini E., (2003a), *Documenti digitali per la conoscenza integrata dei Geositi: l'esempio della Riserva Naturale delle Salse di Nirano*. In Piacente S. & Poli G. (eds.) – *La Memoria della Terra. La Terra della Memoria*. Regione Emilia Romagna. Ed. L'inchiostròblu. Bologna, 121-127.
- Castaldini, D., Gentili, B., Materazzi, M., Pambianchi, G., (eds), (2003b), *Workshop on “Geomorphological sensitivity and system response”*. Camerino- Modena Apennines (Italy), 4-9/07/2003. Proceedings. Università di Camerino – Università di Modena e Reggio Emilia. Arte Lito, Camerino (MC), 175pp.
- Castaldini, D., Valdati, J., Ilies, D. C., (2005a), *The contribution of the geomorphologic mapping to the environmental tourism in protected areas: examples from the Apennines of Modena*

- (Northern Italy), *Revista de Geomorfologie*. Vol. 7, ISSN 1453-5068, 91-106.
- Castaldini, D., Valdati, J., Ilieş, D. C., Barozzini, E., Bartoli, L., Dallai, D., Del Prete, C., Sala, L., (2005b), *Carta Turistico Ambientale dell'Alta Valle delle Tagliole, Parco del Frignano*, Parco del Frignano, Eliofofotecnica Barbieri, Parma.
- Castaldini, D., Valdati, J., Ilieş, D. C., Chiriac C., with contributions by Bertogna I., (2005c), *Geotourist map of the Natural Reserve of Salse di Nirano (Apennines of Modena, Northern Italy)*, *Il Quaternario, Italian Journal of Quaternary Sciences* 18 (1) – Volume Speciale, 245-255.
- Castaldini, D., Conti, S., Conventi, M., Dallai, D., Del Prete, C., Fazzini, M., Fontana, D., Gorgoni, C., Ghinoi, A., Russo, A., Sala, L., Serventi, P., Verri, D., Barbieri, M., (2007), *Le Salse di Nirano*, CD ROM. Enciclopedia Multimediale. Comune di Fiorano Modenese.
- Castaldini, D., Coratza, Paola, Bartoli, L., Dallai, D., Del Prete, C., Dobre, R., Panizza, M., Piacentini, D., Sala, L., Zucchi, E., (2008), *Carta Turistico Ambientale del Monte Cimone, Parco del Frignano*, Parco del Frignano, Eliofofotecnica Barbieri, Parma.
- Castaldini, D., Valdati, J., Ilieş, D. C., (In print), *Geomorphological and Geo-tourist maps of the Upper Tagliole Valley (Modena Apennines, Northern Italy)*, *Il Quaternario, Italian Journal of Quaternary Sciences – Volume Speciale*.
- Desio, A., (1927), *Laghi di circo e tracce glaciali nei dintorni di Fiumalbo*, *Natura*, 18, 95-119.
- De Stefani, C., (1887), *I depositi glaciali dell'Appennino di Reggio e di Modena*, *Atti Soc. Tosc. Sc. Nat., Proc. Verb.*, 5, 206-211.
- Deville, E., Prinzhofner, A., (2003), *Vulcani di fango*, *Le scienze*, 421, 84-90.
- Dimitrov, L. I., (2002), *Mud volcanoes-the most important pathway for degassing deeply buried sediments*, *Earth-Science Reviews* 59, 49-76.
- Ferrari, C., Panizza, M., (a cura di), (1992), *Oltre il limite degli alberi*, *Assessorato Ambiente e difesa del suolo, Regione Emilia-Romagna*, 270 pp.
- Ferrari, C., Vianello, G., (1985), *Le Salse dell'Emilia-Romagna*, Regione Emilia-Romagna, Collana Assess. Ambiente, 116-118.
- Gorgoni, C., (2003), *Le salse di Nirano e le altre salse emiliane - I segreti di un fenomeno tra mito e realtà*, Comune di Fiorano Modenese. Tip. ABC, Sesto Fiorentino (Firenze), 128 pp.
- Jaurand, E., (1999), *Il glacialismo negli Appennini. Testimonianze geomorfologiche e riferimenti cronologici e paleoclimatici*, *Boll. Soc. Geogr. Ital.*, Roma, 12, 6, 399-432.
- Kopf, A., (2002), *Significance of mud-volcanism*, *Review of Geophysics*, 40 (2), 1-52.
- Limonov, A. F., Woodside, J., Cita, M., Ivanov, M. K., (1996), *The Mediterranean Ridge and related mud diapirism, a background*, *Marine Geology* 132, 7-19.
- Losacco, U., (1948), *Tracce glaciali dell'Appennino modenese*, *Boll. Sez. Fiorentina CAI*, 25-28.
- Losacco, U., (1949), *La glaciazione quaternaria dell'Appennino settentrionale*, *Riv. Geogr. Ital.*, 56, 1-142.
- Losacco, U., (1982), *Gli antichi ghiacciai dell'Appennino settentrionale. Studio morfologico e paleogeografico*, *Atti Soc. Nat. e Mat. di Modena*, 113, 1-224.
- Martinelli, G., Judd, A., (2004), *Mud volcanoes of Italy*, *Geol. J.*, 39, 49-61.
- Mazurenko, L. L., Soloviev, V. A., (2003), *Worldwide distribution of deep-water fluid venting and potential occurrences of gas hydrate accumulations*, *Geo-Mar. Lett.*, 23, 162-176.
- Mucchi, A. M., (1966), *Il fenomeno delle salse e le manifestazioni del Modenese*, *Atti Soc. Nat. Mat. Modena*, 97, 1-31.
- Panizza, M., (1992), *Geomorfologia*, Pitagora Ed, Bologna, 397 pp.
- Panizza, M., (2005), *Foreword*, *Il Quaternario, Italian Journal of Quaternary Sciences* 18 (1) – Volume Speciale, p. I.
- Pantaneli, D., (1886), *I cosiddetti ghiacciai Appenninici*, *Atti Soc. Tosc. Sc. Nat., Proc. Verb.*, 5, 142-148.
- Papotti, D., (2002), *Riflessioni preliminari ad una standardizzazione della simbologia per l'escursionismo*, *Bollettino dell'A.I.C.*, no. 114-115, 55-66.
- Pasuto, A., Soldati, M., Siorpaes, C., (2005), *Carta Geomorfologica dell'area circostante Cortina d'Ampezzo (Dolomiti, Italia)*, Carta a scala 1: 20.000, S.E.L.C.A., Firenze.
- Pellegrini, M., Brazzorotto, C., Forti, P., Francavilla, F., Rabbi E., (1982), *Idrogeologia del margine pedeappenninico emiliano-romagnolo*, In G. Cremonini & F. Ricci Lucchi (eds.) – *Guida alla geologia del margine appenninico-padano*. Guida Geol. Reg. Soc. Geol. It., Bologna 183-189.
- Pliny, The Elder, (around 50 A.D.), *Historia Mundi Naturalis*, Book II-85. Einaudi Ed., Torino.

- Ramazzini, B., (1698), *De Petrolio Montis Zibinii*, Modena.
- Regione Emilia-Romagna, (2002), *Itinerari geologico-ambientali nella Val Trebbia. Carta a scala 1: 30.000*, Eliofototecnica Barbieri, Parma-S.EL.CA., Firenze.
- Sacco, F., (1893), *Lo sviluppo glaciale nell'Appennino settentrionale*, Boll. C.A.I. 27, 263-282.
- Sacco, F., (1941), *Il glacialismo dell'Appennino*. L'Universo, 22, 569-602.
- Scicli, A., (1972), *L'attività estrattiva e le risorse minerarie della Regione Emilia-Romagna*, Artioli Modena, 626 pp.
- Servizio Meteorologico Regionale Della Regione Emilia Romagna, (1995), *I numeri del clima*, Ed. Promodis Italia, Brescia, 305 pp.
- Sestini, A., (1936), *Forme glaciali ed antico limite delle nevi nell'Appennino settentrionale*, Riv. Geogr. Ital., 43, 293-298.
- Spallanzani, L., (1795), *Viaggi alle Due Sicilie e in alcune parti dell'Appennino*, Pavia.
- Stoppani, A., (1873), *Il Bel Paese*, Milano, 651 pp.
- Treves, B., (1985), *Mud volcanoes and shale diapirs. Their implications in accretionary processes. A review*, Acta Naturalia Ateneo Parmense 21, 31-37.