

## GEO-TOURIST MAP OF THE NATURAL RESERVE OF SALSE DI NIRANO (MODENA APENNINES, NORTHERN ITALY)

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This article illustrates the criteria and methods applied for implementing a Geo-Tourist map of the Natural Reserve of "Salse di Nirano". This map is an "original" cartographic elaboration in the field of Italian thematic mapping.

The "Salse" are small mud volcanoes genetically linked to the ascent to the surface of salty and muddy waters mixed with gaseous (methane) and, to a lesser extent, fluid hydrocarbons along tectonic discontinuities produced by overthrusting along the front of the Apennine chain. The mud volcanoes of the Modena Apennines have been known since a long time and have always aroused great interest: they are described in many papers, starting as early as Pliny the Elder, in around 50 A.D.

Since the "Salse di Nirano" are one of the best developed mud-volcano phenomena of the entire Italian territory and among the largest in Europe, in 1982 a Natural Reserve was established in the area by the Emilia-Romagna Region; the reserve territory covers a total area of about 200 ha with elevations ranging from 140 to 308 m.

By means of ArcView GIS computer program a Digital Terrain Model (DTM), a Geomorphologic map and a Geo-Tourist map have been elaborated and will be displayed at the Visitor Center of the Reserve. The orographic arrangement of the territory is effectively illustrated by DTM, which was implemented on the basis of altimetric data of the Regional Technical Map (CTR) of the Emilia-Romagna Region. The detailed geomorphologic features are represented in a Geomorphologic map, elaborated on the basis of bibliographic research, interpretation of aerial photographs and field survey. In the study area, where silty-clay soil types (Plio-Pleistocene in age) crop out, landforms and deposits resulting from the endogenetic activity of the mud volcanoes, running water, gravity, anthropogenic activities and polygenetic landforms were recognized. The Geo-Tourist map was derived (with appropriate simplifications and integration) from the Geomorphologic map. The Geo-Tourist map combines the most evident geomorphologic features (mud volcanoes, badlands, landslides, anthropogenetic landforms, bedrock, surface deposits, ponds, marshes etc.) – which can be observed and recognized even by non-experts – with fundamental tourist information (main roads, parking places, visitor center, excursion trails, picnic areas, panoramic points, restaurants and places to stay). The Geo-Tourist map and DTM are the characterizing documents of a new tourist map of the Reserve (Tourist-Environmental map). In particular, the Geo-Tourist map is a foldable, pocket-size, front/rear printed map, with explanatory notes in Italian and English: it was published with the financial support of the Municipality of Fiorano Modenese. This article proves that geomorphologic research can effectively contribute to the implementation of documents and maps useful in the field of tourism.

RIASSUNTO: D. Castaldini et al., *Carta Geo-turistica della Riserva Naturale delle Salse di Nirano (Appennino modenese, nord Italia)*. (IT ISSN 0394-3356, 2005).

Il presente articolo illustra i criteri e la metodologia applicati per la realizzazione della Carta Geo-Turistica della Riserva Naturale Regionale delle Salse di Nirano, che rappresenta un documento "originale" nella panoramica della cartografia tematica italiana.

Le "salse" sono dei piccoli vulcani di fango geneticamente connessi a risalita in superficie di acqua salata e fangosa frammista ad idrocarburi principalmente gassosi (metano) e, in piccola parte, liquidi (petrolio), lungo discontinuità prodotte dagli accavallamenti frontali dell'Appennino. Le salse dell'Appennino modenese sono note da molto tempo ed hanno da sempre suscitato grande interesse: sono state descritte in numerosissimi lavori, già a partire da Plinio il Vecchio nel 50 d.C. Essendo il campo delle Salse di Nirano, uno dei fenomeni pseudo-vulcanici meglio sviluppati su tutto il territorio italiano e tra i maggiori d'Europa, la Regione Emilia-Romagna nel 1982 vi ha istituito una Riserva Naturale che occupa una superficie totale di circa 200 ha ed è compresa fra i 140 e i 308 m di quota.

Per facilitare al visitatore la lettura e la comprensione del paesaggio della riserva sono stati elaborati, utilizzando il Sistema Informativo Territoriale ArcView, un Modello Digitale del Terreno (DTM), una Carta Geomorfologica e una Carta Geo-Turistica che saranno esposti al Centro Visite della Riserva. L'assetto orografico del territorio è efficacemente reso dal DTM, realizzato sulla base dei dati altimetrici della Carta Tecnica Regionale (CTR) della Regione Emilia Romagna. Gli aspetti geomorfologici di dettaglio sono rappresentati in una Carta Geomorfologica, realizzata sulla base di una ricerca bibliografica preliminare, dell'interpretazione di fotografie aeree e mediante rilevamenti sul terreno. Nell'area di studio, dove affiorano esclusivamente litologie limo-argillose (del Plio-Pleistocene), sono state riconosciute forme e depositi legati al fenomeno "endogeno" delle salse, per acque correnti superficiali, gravitativi di versante, antropici e poligenetici. La Carta Geo-Turistica è stata derivata (con appropriate semplificazioni ed integrazioni) dalla Carta Geomorfologica. La Carta Geo-Turistica coniuga la rappresentazione dei più evidenti aspetti geomorfologici (salse, calanchi, frane, opere antropiche, litologia del substrato e depositi superficiali, specchi d'acqua, paludi ecc.), che possono essere osservati e riconosciuti anche da persone non esperte, con l'indicazione delle informazioni turistiche fondamentali (punti di accesso, parcheggi, centro visite, percorsi escursionistici, aree di sosta attrezzate, punti panoramici, punti di ristoro e di pernottamento). La Carta Geo-Turistica e il DTM sono i documenti caratterizzanti di un nuovo depliant turistico della Riserva (Carta Turistico-Ambientale). Questo nuovo documento è un pieghevole, di formato tascabile, stampato fronte/retro con note illustrative in italiano e in inglese: è stato stampato con il contributo finanziario del Comune di Fiorano Modenese. Il presente articolo testimonia come la ricerca geomorfologica possa efficacemente contribuire alla realizzazione di documenti utilizzabili nel settore turistico.

Keywords: Mud volcanoes, Geomorphology, Geo-Tourist Map, Modena Apennines, Northern Italy.

Parole chiave: Salse, Geomorfologia, Carta Geo-Turistica, Appennino Modenese, Italia Settentrionale.

## 1. FOREWORD

In the past few years several studies have been carried out both at an international (e.g., Wimbledon *et al.*, 1995; Dixon, 1996; Eberhard, 1997; Hose, 1997; Barrettino *et al.*, 1999; Johansson & Zarlenga, 1999; Coratza & Marchetti, 2002; Reynard *et al.*, 2003) and national (e.g. Carton *et al.*, 1994; Benvenuti *et al.*, 1998; Bertacchini *et al.*, 1999; Panizza, 2001; Poli, 1999; Piacente *et al.*, 2000; Piacente & Poli, 2003) level for the preservation of Geologic Heritage (whose elements are defined, according to the various authors, as “Geologic Assets”, “Geotopes”, “Geosites” or “Geomorphosites”) and its diffusion and appraisal also outside the realms of academic research. For a general discussion on this topic, see Panizza & Piacente (2003).

This paper is about the “Salse di Nirano” geosite, which makes up the only endogenous forms found in the Modena Apennines.

From a general viewpoint, mud volcanoes are remarkable geologic features formed by semi-liquid and gas-enriched mud breccias extruded from deep sediment layers on the ground surface or on seafloors (cf. Dimitrov, 2002 and references in it; Deville & Prinzhofer, 2003). 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. 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. For example, the Azerbaijan mud volcanoes attain a height of some 500 m.

Also the mud volcanoes of the Modena Apennines are genetically linked to the ascent to the surface of salty and muddy waters mixed with hydrocarbons along tectonic discontinuities produced by the overthrusting of the Apennine chain front (illustrated in the geologic section). The name “salsa” results from the high “salt” content of these muddy waters. The shape of the ejection apparatus depends on the density of the muddy mixture: if it is dense, “cones” (single, double or multiple) of height ranging from a few decimeters to some meters may develop; if the muddy mixture is liquid, ground level “pond-shaped” mud-volcanoes (diameters ranging from a few decimeters to some meters) are formed.

The mud volcanoes of the Modena Apennines have been known for a long time and have always aroused great interest. They were first described by Pliny the Elder, in around A.D. 50, in his monumental “Naturalis Historia”. Pliny the Elder described the eruption of a mud volcano in the Modena district (but it is not known to which one he referred) with the much exaggerated terms of “*crepitu maximo... flamma fumoque*”. Other scientists after him, especially in the 17<sup>th</sup> and 19<sup>th</sup> centuries, described the mud-volcano activity with the same fantastic attributes of impressiveness and spectacularity (e.g. Ramazzini, 1698; Spallanzani, 1795). In particular, at the end of the 19<sup>th</sup> century the Abbot Stoppani described the “Salse di Nirano” com-

paring 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. Pantanelli & Santi, 1896; Biasutti, 1907; Barbieri, 1947; Mucchi, 1966 and 1968; Bertolani, 1980; Ferrari & Vianello, 1985; Bertacchini *et al.*, 1999; Castaldini *et al.* 2003; Gorgoni, 1998 and 2003).

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.

The “Salse di Nirano” are one of the best developed mud-volcano phenomena of the entire Italian territory and among the largest in Europe.

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 (Tosatti, 2002). In this way, the fruition of the area for scientific, cultural, educational and recreational purposes was attained.

Within the framework of investigations for assessing and appraising Geosites in the Italian landscape, and in collaboration with the Board administering the Reserve (Municipality of Fiorano Modenese), a Digital Terrain Model (DTM), a Geomorphologic map and a Geo-Tourist map have been elaborated and will be displayed at the Visitor Center of the Natural Reserve of Salse di Nirano (named “Ca’ Tassi”). These should help to explain the landscape of the Reserve to tourists. In particular, this article illustrates the criteria and methodology applied for implementing a Geo-Tourist map which combines the illustration of the most significant geologic-geomorphologic aspects with fundamental tourist information.

## 2. GEOGRAPHIC AND GEOLOGIC OUTLINE OF THE STUDY AREA

The Natural Reserve of Salse di Nirano is located in the western sector of the Modena Apennine margin, which belongs to the Northern Apennines (Fig. 1). The territory of the Natural Reserve covers a total area of about 200 ha with elevations ranging from 140 and 308 m a.s.l. The area where the mud volcanoes are found covers about 10 ha and is situated at the bottom of a wide sub-circular depression at an altitude of about 200 m.

The setting up of new structures – such as a large parking lot, a new footpath leading to the mud-volcano fields, some resting areas and a road leading to the Ca’ Tassi Visitor Center – have facilitated the fruition of the Reserve, which was visited by 30,000 people in the year 2003. This influx of visitors also shows that this “small green belt” of the lower Modena Apennines is in a strategic position from the tourist viewpoint.

As for climate, the study area is comprised within the Sub-continental temperate climate with average precipitation of about 800 mm/year and average temperatures of 12 to 13 °C (see Servizio Meteorologico della Regione Emilia-Romagna, 1995).

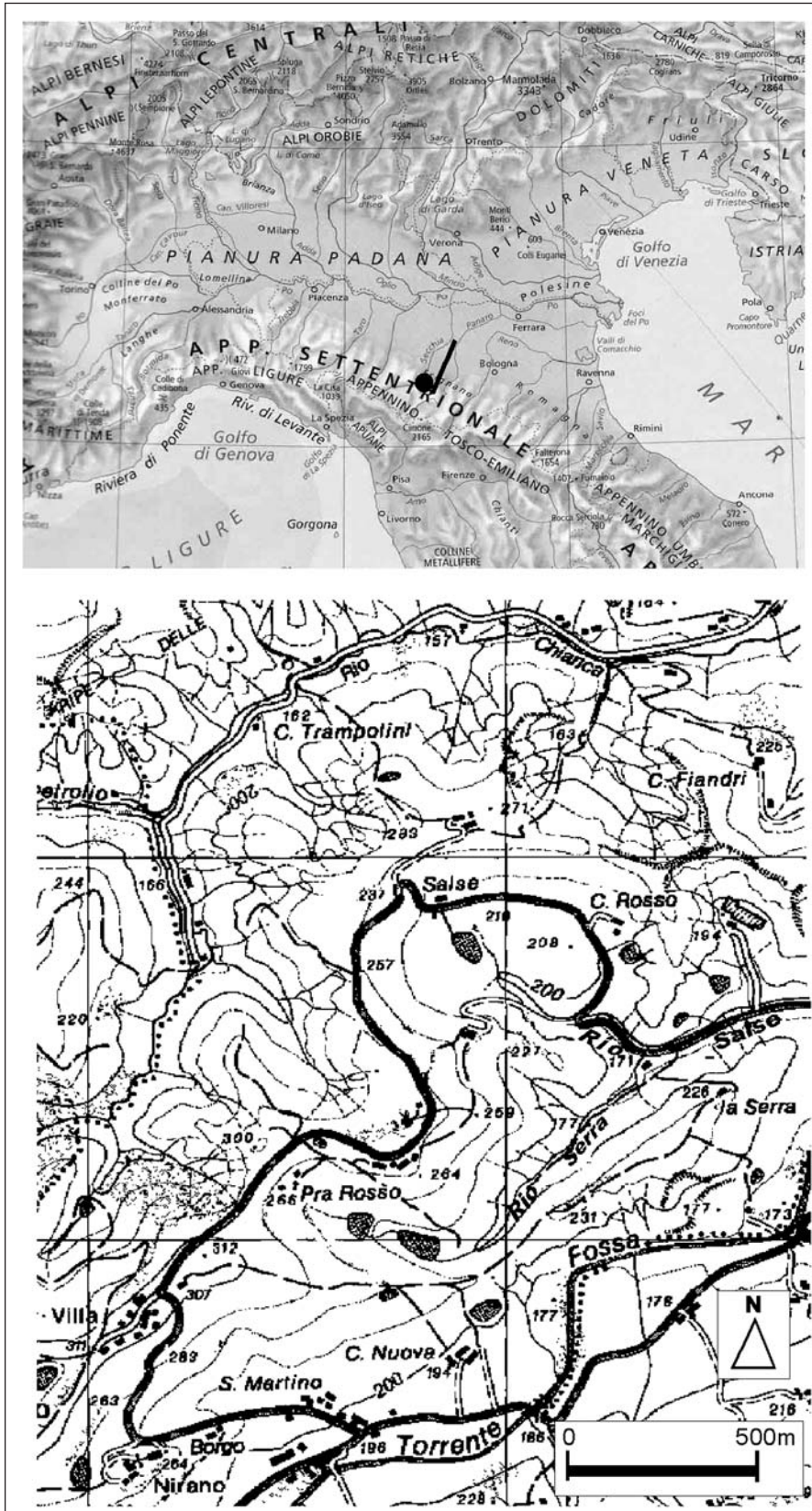


Fig. 1 - Upper part: location of the Natural Reserve of Salse di Nirano (point) and of the geologic cross section of Fig. 2 (line). Lower part: the Natural Reserve of Salse di Nirano in the Regional Technical Map (CTR) of the Emilia-Romagna Region (Tav. 219 NO Sassuolo).

Parte superiore: ubicazione della Riserva Naturale delle Salse di Nirano (punto) e del profilo geologico di Fig. 2 (linea). Parte inferiore: la Riserva Naturale delle Salse di Nirano nella Carta Tecnica Regionale (CTR) della Regione Emilia-Romagna (Tav. 219 NO Sassuolo).

From a geologic standpoint, the Modena Apennine margin is characterized by prevalently compressive structures which correspond to the so called “Emilia Folds” (Pieri & Groppi, 1981; Castellarin *et al.*, 1985; Gasperi *et al.*, 1989). Tectonic structures have been produced by north-bound translational movements (occurring mainly during the Messinian and Pliocene) which affected both the Apennine Chain and the plain which lies in front of it. These movements led to the sequence of thrusting and décollement structures and controlled to some extent the sedimentation rate in the plain (Fig. 2). Sediments ranging from the Lower Pliocene to the Lower Pleistocene outcrop almost continuously in this area. To the south, these deposits are usually transgressive on the Ligurian Units (made up of deep-sea sediments followed by thick sequences of Cretaceous to Eocene calcareous or terrigenous turbidites); to the north, towards the Po Plain, they are covered by alluvial deposits of the Middle-Upper Pleistocene. In the Apennine margin many faults and folds affecting the marine Quaternary sediments, indicate a Middle Pleistocene uplift of the Apennine sector with respect to the plain and a tendency of the southern structures to overthrust the northern structures (Castaldini *et al.*, 1988).

The present day tectonic activity of the Apennine margin is shown by earthquakes that, in this area, are mostly concentrated along the plain-hill boundary. Among the most intense seismic events, the quakes of 1438 (VIII MCS), 1501 (VIII-IX), 1547 (VIII), 1818 (VII-VIII), 1971 (VII-VIII) should be mentioned (cf. Gruppo di Lavoro CPTI, 1999). In the past, some authors noted a correspondence between episodes of violent activity of the mud volcanoes and earthquakes (cf. Stohr, 1869; Pantanelli & Santi, 1896; Pellegrini *et al.*, 1982; Gorgoni *et al.*, 1988). More recent investigations (Gorgoni, 1998 and 2003) have shown that the activity of the mud volcanoes is influenced by local seismicity, some days before the occurrence of rather strong earthquakes.

### 3. GEOMORPHOLOGIC FEATURES OF THE NATURAL RESERVE

In order to offer detailed information about the physical landscape of the Reserve area, a Geomorphologic map and a Digital Terrain Model (DTM) have been realized by means of ArcView GIS computer program. The topographic basis for their elaboration was the Regional Technical Map (CTR) of the Emilia-Romagna Region (1:5,000 scale) (Fig. 3).

The general morphologic picture of this territory is effectively provided by the DTM (Fig. 4) which was computer-elaborated through the transformation of altimetric data (5 m equidistance contour lines) into a Triangular Irregular Network (TIN). By examining it, the presence of a sub-circular shaped depression, similar to a caldera, is quite evident even to non-experts: on the floor of this depression the mud volcanoes are found. An explanation is that this form is the result of a progressive gravitational collapse due to the constant depletion of mud ejected from the vents (Bertacchini et al., 1999). Another hypothesis is that the depression could be the result of a collapse in correspondence of a “mud-diapir” at the end of its uplifting activity (personal communication by G. Bettelli). Indeed, this hypothesis seems to be more plausible, because it explains not only the depression itself, but also its sub-circular shape.

Also the “calanchi” (badlands) are quite evident in the DTM. These are one of the most spectacular forms of erosion, similar to badlands, of the Apennine margin (Fig. 5). They are typical of clayey soils and are characterized by a very fine drainage network and short, steep slopes with narrow interfluvies. 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.

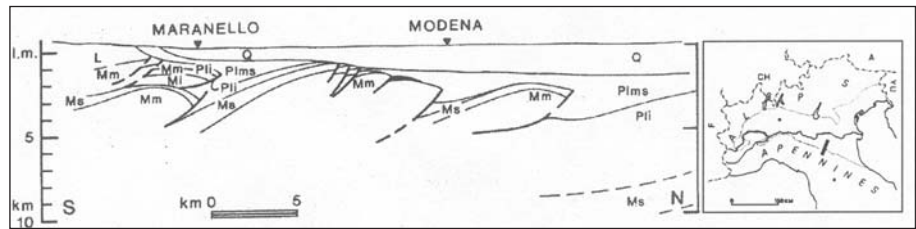


Fig. 2 - Geologic cross section of the Modena Apennine margin and plain (after Gasperi et al., 1989). Q: Quaternary; PliMs: Upper-Middle Pliocene; Pli: Lower Pliocene Ms: Upper Miocene; Mm: Middle Miocene; Mi: Lower Miocene; L: Ligurian Units.

*Profilo geologico del margine appenninico e dell'alta pianura modenese (da Gasperi et al., 1989). Q: Quaternario; PliMs: Pliocene medio-superiore; Pli: Pliocene inferiore; Ms: Miocene superiore; Mm: Miocene medio; Mi: Miocene inferiore; L: Liguridi.*

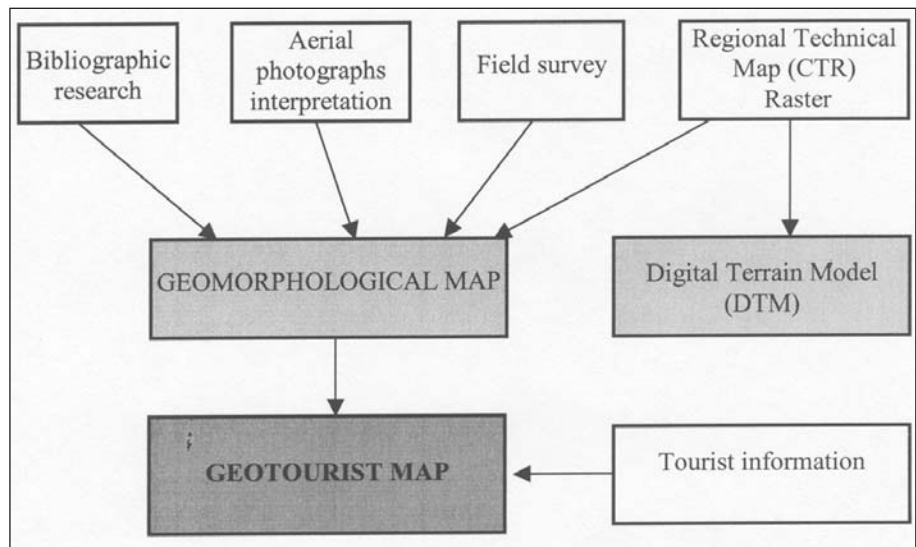


Fig. 3 - Scheme of elaboration of the various documents.

*Schema di elaborazione dei vari documenti.*

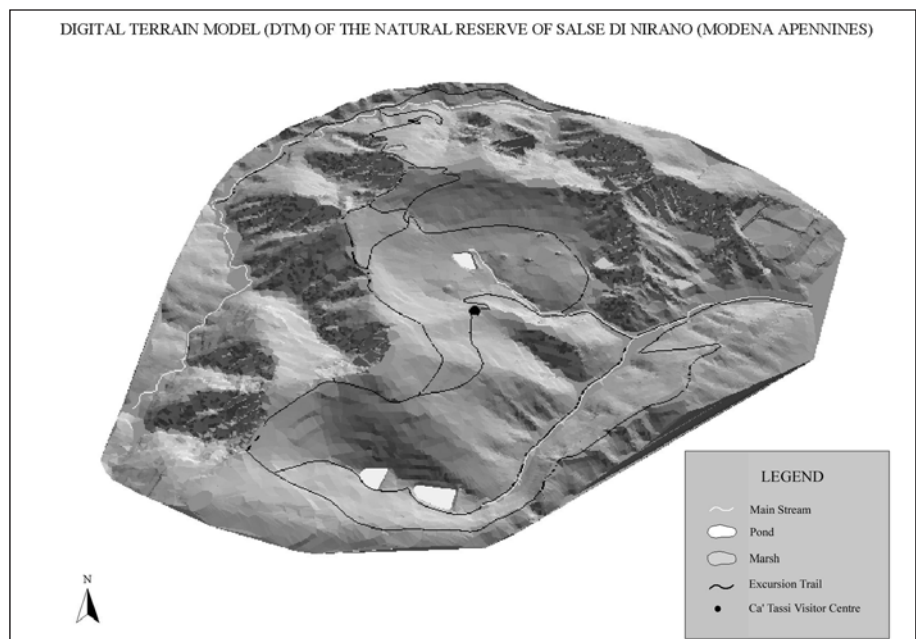


Fig. 4 - Digital Terrain Model (DTM) of the Natural Reserve of Salse di Nirano (Modena Apennines).

*Modello Digitale del Terreno (DTM) della Riserva Naturale delle Salse di Nirano (Appennino Modenese).*

Detailed morphologic aspects are illustrated in a Geomorphologic map, resulting from bibliographic research, analysis of recent aerial photographs (1994 and 1998/99) and field survey. In drawing up the Geomorphologic map of the study area (Fig. 6) the legend set up by Gruppo Nazionale Geografia Fisica e Geomorfologia (1994) was applied with some modifications.

In the reserve area only silty-clay soil types (Plio-Pleistocene in age) crop out: the "Argille del T. Tiepido" (marine silty-clays) which are found nearly all over the territory and the "Argille del Rio del Petrolio" (marine marly-clays) cropping out to the north. The study area is characterized by the presence of two systems of tectonic discontinuities (faults and/or fractures), NW-SE and SW-NE oriented, respectively. These discontinuities have been identified by means of aerial photo interpretation and field observations of the mud volcanoes arrangement, which shows a clear alignment (Fig. 7).

The main streams are the Rio Chianca (which marks the western and northern boundary of the park), Rio delle Salse and its tributary Rio Serra which, as previously stated, flow in the southern sector of the Reserve. In addition, some small reservoirs are also found: three ponds and four marshy areas. Another four relict ponds have been completely filled by palustrine deposits. Their origin is artificial as witnessed by the presence of artificial embankments downstream.

The geomorphologic map (Fig. 6) does not show the precise number of the mud-ejecting points but simply their location, distinguishing between cone-shaped mud volcanoes (Fig. 7) and pond-shaped mud volcanoes (Fig. 8). The morphology of this area is, in fact, constantly evolving with the formation of new craters whilst others cease their activity.

The activity of a salsa is influenced by meteorologic factors. In summer, the activity may decrease due to the muds' de-hydration until the possible obstruction

of the up-welling channel occurs. During wetter seasons, due to the terrain softening and to the increasing methane's pressure accumulating deeper down, the obstruction can be demolished and the activity may restart. During non-active periods, the mud volcanoes are subject to erosion by precipitation water and can be partially dismantled, until the following activity phases when they are rebuilt. The number of apparatuses can vary with time, as well as their location: in the case of Nirano, the mapping and photographic documents point to a considerable steadfastness during the past one hundred years (Gorgoni, 2003).

During our survey, five main groups of cone-shaped mud volcanoes and three main groups of pond-shaped ones were found. The clayey materials ejected from the craters cover the surrounding ground with mudflows. Therefore, owing to the constant emission of mud over time, the floor of this depression is covered by fine-grained deposits up to a few meters in thickness.

The main anthropogenetic landforms are found near the eastern entrance to the Reserve. They are: i) an abandoned quarrying area, modeled at present by the running waters which have created the badlands, gullies and colluvial deposits; ii) a parking area for visitors and iii) an artificially flattened area corresponding to a disused farming area (a worm "farm" for anglers). Furthermore, the areas affected by creep due to grazing, which are concentrated on the northern slopes of the Reserve, are also shown. This man-induced process is made evident by the step-like shape of the slopes created by pasturing sheep. By reducing the grass cover of the soil, these animals have also favored the onset of solifluction.

The numerous crests and watersheds have been considered as polygenetic forms. Indeed, while the sub-circular crest which surrounds the mud-volcano depression is probably linked to a gravitational collapse, other watersheds were created by retrogradation of the badland heads.

The landforms and deposits due to running waters are particularly widespread. Nearly everywhere it is possible to observe badlands ("calanchi") in most cases stabilized by vegetation. Small earth flows, in most cases stabilized, fill the erosion furrows at the foot of the badlands; they too are shown on the geomorphologic map. Also the main gullies are indicated. Deposits have been indicated only where their thickness exceeds 1 m. They are mostly made up of very fine materials deposited by the main watercourses (concentrated on the floor of the small valleys of Rio Chianca, Rio Serra and Rio delle Salse) and colluvial deposits (particularly widespread at the foot of the northern slope of the mud volcanoes depression).

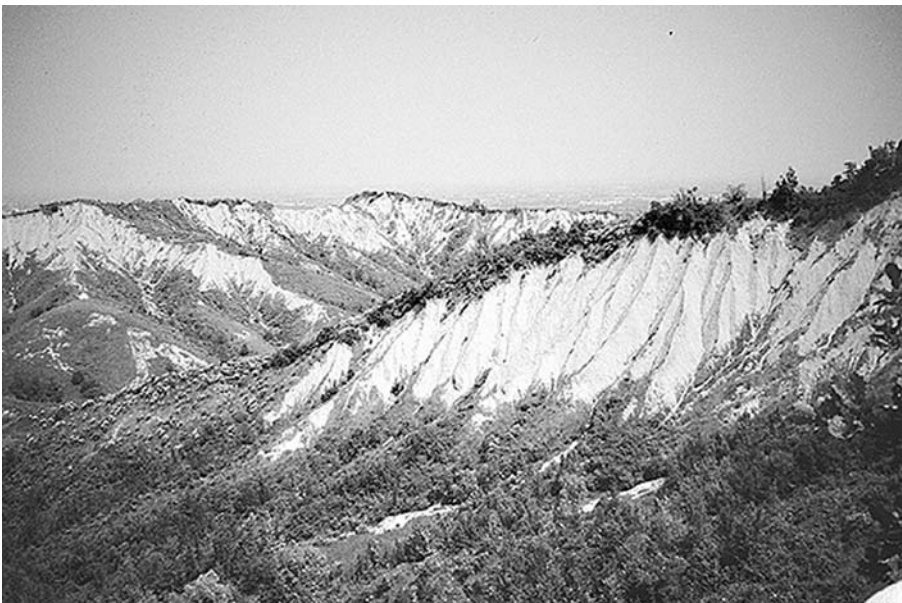


Fig. 5 - The "calanchi" (badlands) of the Rio Chianca Valley in the northern sector of the Reserve.

*I calanchi della valle del Rio Chianca nel settore settentrionale della Riserva.*

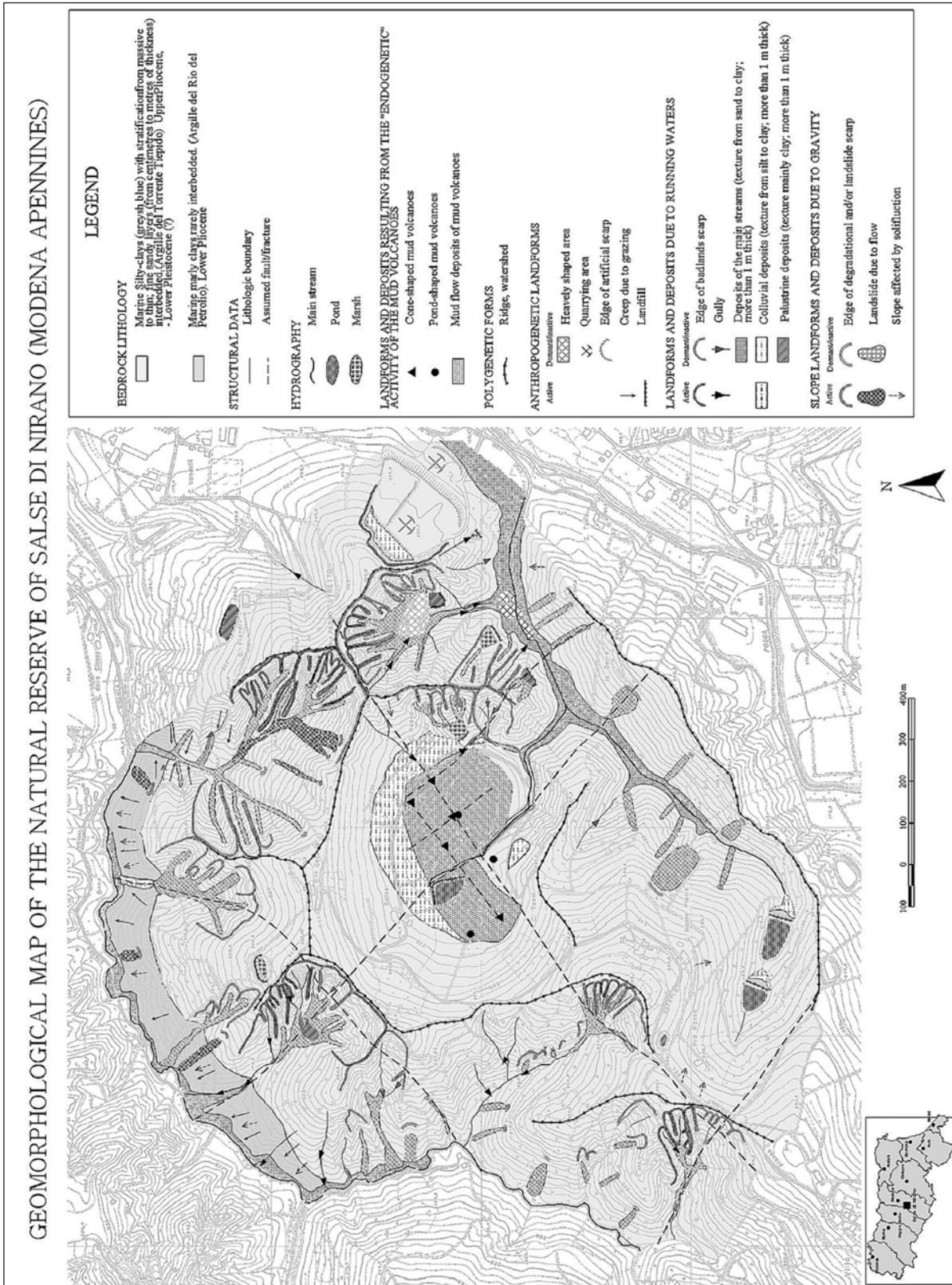


Fig. 6 - Geomorphologic map of the Natural Reserve of Salse di Nirano (Modena Apennines).  
 Carta Geomorfologica della Riserva Naturale delle Salse di Nirano (Appennino Modenese).

Landslide bodies and relative detachment scarps are quite common all over the Reserve; they are landslides classified as small earth flows. Most landslide deposits have been colonized by spontaneous vegetation which has contributed to stabilizing them and making them poorly visible in the field. Solifluction makes up a secondary process particularly widespread in the northern part of the Reserve, where it has been favored by creep due to grazing.



Fig. 7 - Cone-shaped mud volcanoes. They show a clear alignment in correspondence with a fault/fracture.

*Salse "a cono". Esse sono chiaramente allineate lungo una faglia/frattura.*



Fig. 8 - Pond-shaped mud volcano.

*Salsa a "polla".*

#### 4. GEO-TOURIST MAP

A Geo-Tourist map can be considered as a thematic map; these are maps which focus on a particular aspect (cf. Sestini, 1981; Mori, 1990) and, consequently, are aimed at specific categories of users.

First of all, in the preparation of a thematic map, the set of data that are to be emphasized must be chosen, namely the setting up of a language and mapping system (cf. Papotti, 2002).

Therefore, a Geo-Tourist map should combine geologic-geomorphologic data with tourism data. The Geo-Tourist map here illustrated was derived (with appropriate simplifications and integration) from the Geomorphologic map and combines the most evident geologic-geomorphologic aspects with basic tourist information (Fig. 3). The Geo-Tourist map, which was originally produced in color, is here presented in black and white (Fig. 9).

The goal of this study was to make a map which could be easy to read for a tourist of average education. Since the immediacy of a map depends essentially on the simplicity of the symbols used, we deliberately avoided the setting up of a legend finalized to the completeness of data, which would have implied a long list of symbols. Considering that the more symbols are added the more is lost in clarity, the use of symbols was limited to the essential ones. In particular, the legend was subdivided into two clearly distinct sectors. In the first sector the symbols representing geologic and geomorphologic aspects are illustrated, whereas in the second one the symbols concerning tourism information are shown.

Regarding the geomorphologic aspects, the Geo-Tourist map pinpoints all the elements of the landscape that a tourist can observe and identify. An effort was made to use simple, clear, graphically pleasing symbols with short captions, avoiding specialized terminology. In any case, the legend adopted is scientifically correct. From the practical viewpoint, using the Geomorphologic map as a starting point, the following criteria of elaboration have been applied: i) as regards the mud

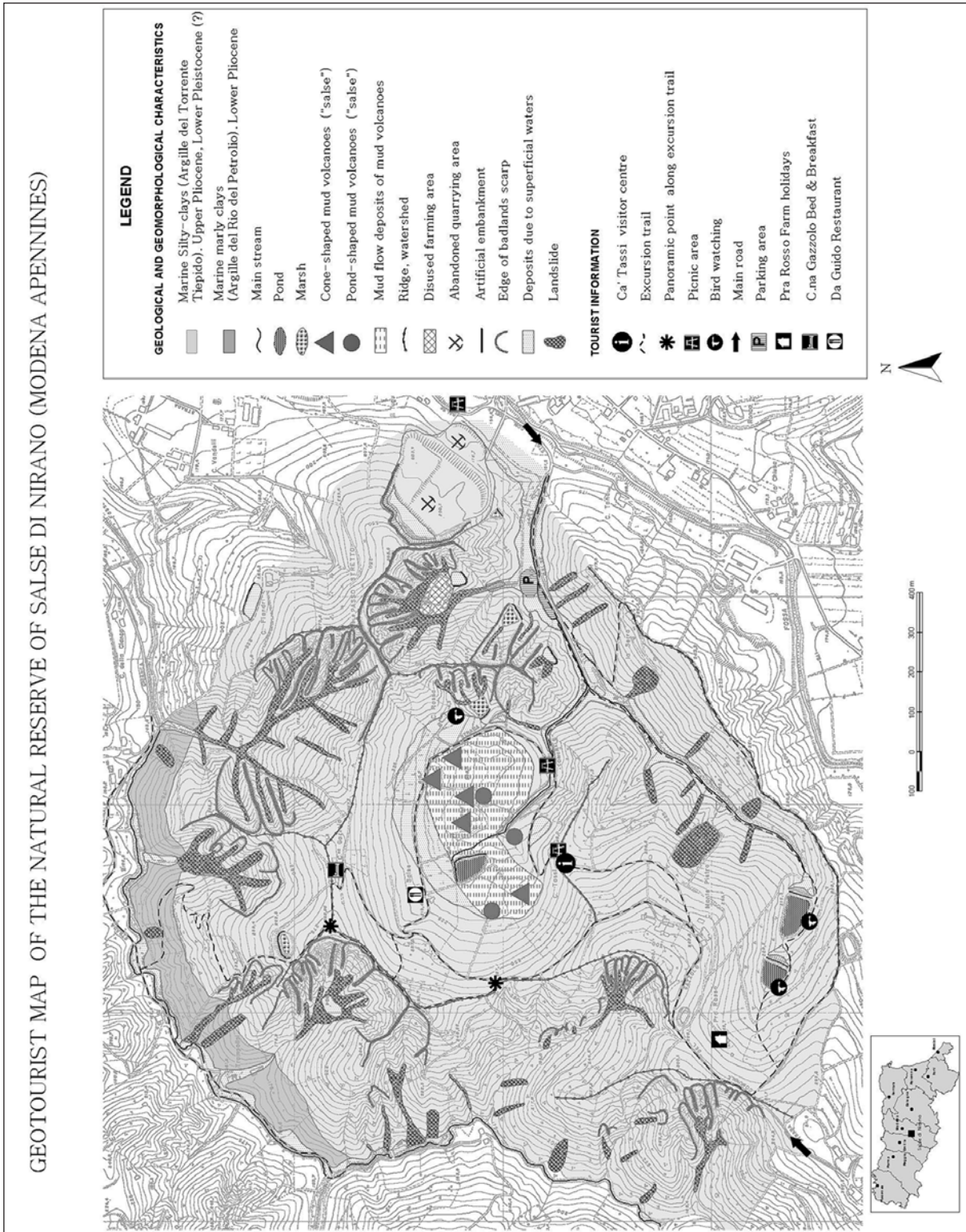


Fig. 9 - Geo-Tourist map of the Natural Reserve of Salse di Nirano (Modena Apennines).  
 Carta Geotouristica della Riserva Naturale delle Salse di Nirano (Appennino Modenese).



volcanoes (“Salse”) – the main attraction of the Reserve – symbols graphically recalling both the “cone-shaped” forms and the “pond-shaped” ones have been adopted; ii) these symbols are shown in particularly evident dimensions, so that the tourist can immediately locate them; iii) the distinction of activity for landforms and deposits has been eliminated; iv) also faults/fractures have been cancelled from the map since they are not easily identifiable in the field; v) the less representative forms (e.g., gullies) and the most difficult ones to be recognized (e.g., slopes affected by solifluction, areas affected by creep due to grazing) have been eliminated; vi) the various types of deposits have been simplified (e.g., a single grouping for deposits due to running waters); vii) in the original version (in color) the range of colors used has been reduced.

As for tourist information, in the original version (in color) this has been indicated with a particularly evident color (red), in order to be immediately recognized by the visitors. The commonly used symbols for tourist maps have also been adopted in this case. They include: i) general information (e.g., Ca’ Tassi visitor center, excursion trails, panoramic points along the excursion trails, picnic areas); ii) wildlife information (bird-watching points); iii) logistic information (main access roads, parking places, refreshment and overnight-stay sites, consisting of a restaurant, a holiday farm and a bed & breakfast).

As previously stated, in the Geo-Tourist map (and in the DTM) the excursion trails are shown in order to facilitate the interpretation of the landscape and its elevation points for the tourist willing to walk along the trails suggested. The trails are as follows: 1) *Tour of the “Salse”*: this trail winds around the core of the Natural Reserve allowing the phenomenon of mud volcanoes to be observed from both close up and from a panoramic viewpoint. 2) *Walk around the ponds*: this trail follows the valley floor of the Rio delle Salse/Rio Serra as far as the two artificial ponds SE of Pra’ Rosso (where bird-watching can be practiced), then it continues upwards as far as the southernmost crest of the Reserve. 3) *Walk from the Salse depression to the Chianca valley*: this comprises some panoramic points from which the view of the entire mud volcanoes depression can be appreciated. Along this trail it is possible to observe at close quarters the western “calanchi” of the Reserve and a typical example of marsh. 4) *Tour of the “calanchi”*: this trail follows prevalently the valley floor of Rio Chianca and allows the observation of several examples of badlands from below.

## 5. CONCLUSIONS

The study here described was finalized to the implementation of a Digital Terrain Model (DTM), a Geomorphologic map and a Geo-Tourist map of the Natural Reserve of Salse di Nirano.

Whereas the first two documents are common within the framework of geomorphologic studies, the Geo-Tourist map is an original document. The goal was to produce a map that could be easily interpreted by tourists with average education and help them to understand the surrounding landscape. Therefore, since the readability of a map depends essentially on

the simplicity of its symbols, only the symbols considered as essential are shown. In particular, the legend was subdivided into two clearly distinct sectors. The first sector shows the symbols representing the geologic and geomorphologic aspects, whereas the second shows the symbols regarding tourist information.

All maps (Geomorphologic map, DTM and Geo-Tourist map) have been implemented by means of ArcView GIS computer program. Therefore, since these documents are presented in the digital format, they can be easily updated and/or integrated with further data.

The DTM and Geo-Tourist map are the characterizing documents of a new tourist foldable on the Reserve (Tourist-Environmental map). The elaboration of the foldable, pocket-size, front/rear printed Tourist-Environmental map has now been completed. This document, which is presented with explanatory notes in Italian and English, was published with the financial support of the Municipality of Fiorano Modenese (Barozzini *et al.*, 2004).

This initiative, which is part of the activities aiming to improve the information, fruition and appraisal of the Region’s Natural Reserve of Salse di Nirano, witnesses how geomorphologic investigations can effectively contribute to the creation of maps utilizable in the tourism field.

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