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Geomorphological and Geotourist Maps of the Upper Tagliole Valley (Modena Apennines, Northern Italy)

Carte geomorfologica e geo-turistica dell'alta Valle delle Tagliole (Appennino Modenese, Italia settentrionale)

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ABSTRACT – This paper considers the geomorphological map and the criteria and methodology used for the production of a geo-tourist map of the upper Tagliole Valley – which is located in the Frignano Park (high Modena Apennines, Italy). These documents, at the 1:10,000 scale, elaborated by means of ArcView GIS computer programme, should help to explain the landscape of this area to tourists. The Regional Technical Map (CTR) of the Emilia-Romagna Region was used as the topographic basis for their elaboration.
The geomorphological features of the study area are represented in detail in the geomorphological map. The landforms and deposits of the upper Tagliole Valley, characterised by arenaceous rock types, may be grouped according to the following systems or groups of morphogenetic factors and processes: structural landforms, glacial landforms and deposits, cryogenetic landforms and deposits, landforms and deposits due to running waters, slope landforms, deposits due to gravity, anthropogenetic landforms.
The geo-tourist map was derived (with appropriate simplifications and integrations) from the geomorphological map. The geo-tourist map combines the most evident geological-geomorphological features (e.g. bedrock, hydrography, glacial landforms and deposits, scarps, ridges, saddles, waterfalls) – which can be observed and recognised even by non-experts – with basic tourist information (e.g., parking places, excursion trails, refuges, picnic areas). The geo-tourist map is the characterising document of a tourist-environmental map of the upper Tagliole Valley.
This article proves that geomorphological research can effectively contribute to the implementation of documents and maps useful in the field of tourism.

KEY WORDS: Glacial landforms, Geomorphological map, Geo-tourist map, Tagliole Valley, Modena Apennines.

RIASSUNTO – Il presente lavoro descrive la carta geomorfologica e i criteri e la metodologia applicati per la realizzazione della carta geo-turistica dell'alta Valle delle Tagliole compresa nel Parco del Frignano nell'Alto Appennino Modenese. Questi documenti, a scala 1:10.000, elaborati utilizzando come strumento tecnologico il Sistema Informativo Territoriale ArcView e come base topografica gli elementi della Carta Tecnica Regionale della Regione Emilia Romagna, sono stati realizzati per aiutare il turista nella lettura e nella comprensione del paesaggio dell'area di studio.
Gli aspetti geomorfologici di dettaglio sono rappresentati nella carta geomorfologica elaborata secondo i criteri classici che prevedono l'indicazione degli aspetti morfogenetici, morfodinamici e morfometrici. In particolare, nell'alta Valle delle Tagliole, dove affiorano esclusivamente rocce arenacee della Formazione del Macigno (Oligocene medio/superiore-Miocene inferiore?), sono state riconosciute forme e depositi appartenenti ai seguenti sistemi di fattori e processi morfogenetici: forme strutturali, forme e depositi glaciali, forme e depositi crionivali, forme e depositi per acque correnti superficiali, forme e depositi gravitativi di versante, forme antropiche.
Nella Valle delle Tagliole il turismo invernale non è sviluppato come in altri settori ma è invece frequentata da escursionisti specialmente nel periodo estivo per l'affascinante paesaggio. Nella valle si rinvengono infatti gli ampi circhi glaciali del M. Rondinaio e del M. Giovo e i laghi Santo, Baccio, Torbido e Turchino.
La carta geo-turistica è stata derivata (con appropriate semplificazioni ed integrazioni) dalla carta geomorfologica e coniuga la rappresentazione dei più evidenti aspetti geomorfologici (es. roccia affiorante, idrografia, forme e depositi glaciali, crinali, selle, scarpate, cascate), che possono essere osservati e riconosciuti anche da persone non esperte,

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con l'indicazione delle informazioni turistiche fondamentali (es. parcheggio, sentieri del Club Alpino Italiano, aree di sosta attrezzata, rifugi). La carta geo-turistica è il documento caratterizzante della carta turistico-ambientale dell'alta Valle delle Tagliole realizzata per il Parco del Frignano.
Il presente lavoro rappresenta un'ulteriore testimonianza di come la ricerca geomorfologica possa efficacemente contribuire alla realizzazione di documenti utilizzabili nel settore turistico.

PAROLE CHIAVE: Forme glaciali, Carta geomorfologica, Carta geo-turistica, Valle delle Tagliole, Appennino Modenese.

1. – INTRODUCTION

This paper describes the geomorphological map and the criteria and methodology used for the production of a geo-tourist map of the upper Tagliole Valley, which is located in the high Apennines of Modena Province, Italy (fig. 1). The geo-tourist map of the upper Tagliole Valley was implemented following the example of the geo-tourist map of the Natural Reserve of Salse di Nirano which is located at the Modena Apennine foothill (BAROZZINI *et alii,* 2004; CASTALDINI *et alii,* 2005b). These "original" geo-tourist maps are part of the initiatives enterprised by public boards for improving the knowledge, utilisation and appraisal of the environment of protected areas.

The upper Tagliole Valley is located in the Frignano Park (the term "Frignano" derived from the ancient pre-Roman people of "Liguri Friniati"), or 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 (2165 m a.s.l.), Mt. Giovo (1991 m) and Mt. Rondinaio (1964 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 zones are located in the municipalities of Fanano, Sestola, Montecreto, Riolunato, Pievepelago, Fiumalbo and Frassinoro.

2. – GEOGRAPHICAL SETTING

The Tagliole Valley is located on the Po Plain side of the Northern Apennines, within the catchment of the Panaro River, in proximity of the main watershed (fig. 1). This valley, located in the municipality of Pievepelago, is one of the most relevant valleys of the Apennines of Modena. The valley takes its name from the Tagliole Torrent which flows through it from south to north; the main hamlets are Le Tagliole, Ronchi and Rotari. In this valley winter tourism is not developed as much as in other areas of the Modena Apennines like, for example, at the Mt. Cimone area. Hikers visit frequently the valley, especially in the summer, because of several lakes in the area.

Climate is considerably influenced by several geographical factors, among which the altitude and location near the watershed (PIACENTE, 1992; SERVIZIO METEOROLOGICO REGIONE EMILIA-ROMAGNA, 1995). Below 1000 m a.s.l., the average annual temperature is 10 °C, whereas above this elevation it progressively decreases to 6 °C. Annual precipitation ranges from 1250 mm in the

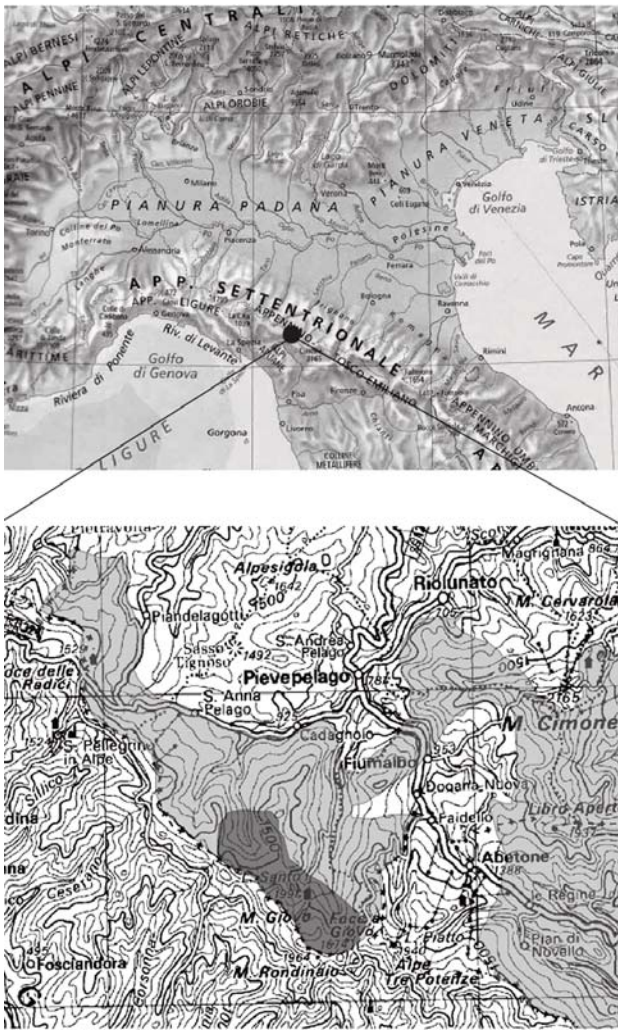

Fig. 1 – Location of the upper Tagliole Valley (Frignano Park, Modena Apennines). Dark grey: study area; Light grey: Frignano Park area.
– Ubicazione dell'alta Valle delle Tagliole (Parco del Frignano, Appennino Modenese) Grigio scuro: area di studio; Grigio chiaro: area del Parco del Frignano.

lower part to over 2000 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.

3. – GEOLOGICAL SETTING

The Modena Apennines belong to the Northern Apennines which are a fold and thrust belt resulting from a complex and multi-staged evolution. The geological structures of the chain are quite complicated (e.g. see BOCCALETTI *et alii,* 1981, CERRINA FERONI *et alii*, 2002).

The main geological units forming the Modena Apennines include (BETTELLI *et alii,* 1989):

1) Tuscan Units, made up of Tertiary siliciclastic deep-water turbidites, continuously cropping out along the Apennine chain's axis.

2) Ligurian Units consist of deep-sea oceanic sediments including Jurassic ophiolites followed by thick sequences of late Cretaceous to middle Eocene calcareous or terrigenous turbidites.

3) Mainly terrigenous epi-Ligurian sequences of Middle Eocene to Late Messinian, age unconformably resting on the deformed Ligurian Units. The epi-Ligurian sequences and the Ligurian Units are exposed in the mid-Apennines.

4) The belt of Plio-Quaternary marine terrigenous deposits unconformably overlying the Ligurian Units and the epi-Ligurian sequence cropping out at the Apennine margin and dipping under the alluvial deposits of the Po Plain.

In particular, the Macigno Formation (belonging to the Tuscan Units) and the Mt. Modino Complex (belonging to the Ligurian Units) crop out in the Tagliole Valley (PLESI *et alii,* 2002). The Macigno Formation (Mid-LateOligocene-Early Miocene?) crops out in the study area; it is made up of sandstones with interbedded thin layers of fine-grained sandstones, siltites and shales. In three different sites, polygenic breccias (Late Oligocene-Early Miocene?) composed of grey and black shales, with grey calcareous marlstone blocks and strongly tectonised multicoloured shale beds and calcareous marlstones with dark shales interbedded, are tectonically found in-between the Macigno Formation and Mt. Modino Complex.

The latter crops out in the northern portion of the valley (Late Oligocene-Early Miocene?). In its lower portion, this formation is composed of multi-coloured shales, marlstones, silty marlstones and siltstones (belonging to the Argilliti di Fiumalbo Formation), followed by thick layers of mid-coarse to fine grained sandstone, with intercalations of marly clays (belonging to the Arenarie di Mt. Modino-Mt. Nuda Formations).

4. – PREVIOUS GEOMORPHOLOGICAL STUDIES AND GEOMORPHOLOGICAL SETTING

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.

The geomorphological studies in this sector of the Northern Apennines have mainly dealt with landforms linked to glacialism. The first investigations on glacialism began at the end of the 19th century.

For instance, DE STEFANI (1887) and SACCO (1893) described moraine deposits, valley lakes and glacial cirques. On the other hand, PANTANELLI (1886) tried to explain the Apennine morphogenesis by means of simple slope processes, even though he admitted the existence of striated pebbles and landforms of uncertain origin.

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, 1949a).

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). This Author is perhaps the only one who provided us with a rather complete and accurate overview of glacial traces in the Northern Apennines.

During the past decades, FEDERICI & SCALA (1966), FEDERICI (1977, 1980), GRUPPO RICERCA GEOMORFOLOGIA C.N.R. (1982), FEDERICI & TELLINI (1983), BERTOLINI & TREVISAN (1984), CARTON & PANIZZA (1988) and CASTALDINI *et alii,* (1998) carried out several investigations on glacial landforms in this sector of the Apennines. Some of them significantly contributed to the knowledge of the geomorphological processes and the methods for reconstructing the Apennine glacial chronology. In fact, in the preceding papers, the glacial traces of the Northern Apennines were always attributed to a single glaciation event, correlated to the Alpine Würm I. Since the late 1970s many authors reported glacial deposits whose location, morphology, lithology and weathering rate could be explained only by previous glaciations

(FEDERICI 1977, 1980; GRUPPO RICERCA GEOMORFOLOGIA C.N.R., 1982; FEDERICI & TELLINI, 1983). The lack of traces of glacial periods older than the Würm in the high Modena Apennines may be explained with the hypothesis that they might be obliterated by erosional processes linked to the considerable uplift of this sector occurring from the Mid-Late Pleistocene and continuing to date (BARTOLINI, 1999).

JAURAND (1999) reviewed the knowledge of the glacialism in the Apennines by trying to attain a more accurate outline of both the last glacial period (maximum of the recent Würm and retreat phases) and the traces of more ancient glaciations.

In this sector of the Nothern 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. According to CASTALDINI *et alii,* (2002b) the most accepted origin (about 65%) of the lakes of the high Emilia-Romagna Apennines is due to glacial processes.

Landforms resulting from periglacial processes (e.g. block streams, block fields, gelifluction deposits etc.) and from the action of surface running water (e.g., gullies, alluvial and colluvial fans, debris flow lobes, 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 some areas of the Northern Apennines.

Among the papers of the past decades containing geomorphological data on the Tagliole Valley the following should be quoted: ALAGNA *et alii* 1987, MAZZA & PANIZZA (1988), BORTOLOTTI (1992), FERRARI & PANIZZA (1992), PANIZZA (1992), BERTACCHINI *et alii* (1999), CASTALDINI (2003).

In particular, MAZZA & PANIZZA (1988) studied the geomorphology of the entire Tagliole valley and published the first geomorphological map of this territory. The topographic basis for its elaboration was the Istituto Geografico Militare (IGM) Map (1: 25.000 scale, updated in 1947).

BERTACCHINI *et alii,* (1999) described the main features of the Tagliole Valley within the framework of an inventory of the geological heritage of the Province of Modena (whose elements are defined, according to the various authors, as "Earth Sciences Sites", "Geological Assets", "Geotopes", "Geosites" or "Geomorphosites"; see REYNARD, 2004).

CASTALDINI (2003) illustrated the geomorphological characteristics of the Tagliole Valley in a guide on the morphology of the Apennines of Modena. In this work, the orographic setting of the valley is effectively shown by a Digital Elevation Model (DEM) which was computer-elaborated through the transformation of altimetric data of the Regional Technical Map (CTR) of the Emilia-Romagna Region (5 m equidistance contours) into a Triangular Irregular Network (TIN).

5. – STUDY METHODOLOGY

Geomorphological and geo-tourist maps, at a 1:10,000 scale, were produced by means of ArcView GIS computer programme to provide information on the physical landscape of the upper Tagliole Valley. The Regional Technical Map (CTR) of the Emilia-Romagna Region was used as a topographic basis for their elaboration.

The detailed morphological features of the study are illustrated in a geomorphological map (see enclosed map), produced from bibliographic research, analysis of aerial photographs and satellite images from various periods (1955, 1973, 1994, 2000 and 2003) and field survey. In implementing this map the legends used for recent geomorphological maps were applied (e.g., CASTALDINI *et alii*, 1998; PASUTO *et alii*, 2005).

The ages shown on the geomorphological map result from bibliographic data and field survey, since no chronological determination was conducted on deposits and related landforms. From a morphodynamic standpoint, landforms and deposits are classified as active (i.e., active processes during field work), or inactive (i.e., not processes tangible during the period field survey was carried out). Obviously, structural and anthropogenetic landforms were excluded from these distinctions.

At a further step of research, a geo-tourist map was derived from the geomorphological map (see enclosed map). As underlined in CASTALDINI *et alii,* (2005b), a geo-tourist map is a thematic map which focuses on a particular aspect and is, consequently, directed to specific users. First of all, in the preparation of a thematic map, the data set to be used should appropriate to a specific language and mapping system (PAPOTTI, 2002). Therefore, a geo-tourist map combines the most evident geological and geomorphological aspects with basic tourist information. The legend consists of two clearly distinct categories one with symbols rep-

resenting the geomorphological characteristics and a second showing symbols concerning to tourist information.

5.1. – Geomorphological Map of the Upper Tagliole Valley

The general morphological context of the upper part of the Tagliole valley is provided by the DEM elaborated by Castaldini (2003) (fig. 2). The Torrent Tagliole flows across this valley from south to north and from 1400 to 1050 m of altitude. On the left hand-side of the stream, at the head of the valley, the wide glacial cirques of Mt. Rondinaio (fig. 3) and Mt. Giovo are quite evident.

The significant difference in elevation between the highest peaks and the valley floor reflexes the high relief energy of this valley. Glacial deposits and moraine ridges occurs at various altitudes; glacial landforms have caused the formation of lacustrine depressions and ponds owing to the barrage of runoff waters. Lake Santo, with its typical "bean-shaped" form, and Lake Baccio, a subcircular small impoundment, are of particular evidence and interest. The slightly inclined wide flat area at north-east of Lake Santo corresponds to a bedding surface. The landforms found on the valley's right-hand side are the result of slope processes.

Detailed information on the geomorphological characteristics of the upper Tagliole Valley are depicted in the geomorphological map (enclosed map). In particular, the study area is on the left hand-side of the valley and includes the northern slopes of Mts. Rondinaio and Giovo.

A comparison of the geomorphological map produced by Mazza & Panizza (1988) with the geomorphological map elaborated in this research, it comes out that the latter takes into account a smaller sector of the Tagliole Valley,which has a more recent topographic basis at a greater scale (1:10.000 scale, updated in 1988 vs. 1:25.000 scale, updated in 1947), and makes reference to legends used in recent geomorphological maps.

The landforms and deposits of the Tagliole Valley may be mainly classified according to the following systems or groups of morphogenetic factors and processes: glacial landforms and deposits, cryogenetic and nivation landforms and deposits, structural landforms, landforms and deposits due to running waters, slope landforms and deposits due to gravity, anthropogenetic landforms.

The hydrographic characteristics of the study area include perennials streams, lakes and ponds (distinguished in perennial and temporary) and springs. The main streams are Fosso del Lago Santo, Fosso del Lago Baccio and Fosso del Balzone, which are left hand-side tributaries of Torrent Tagliole and Rio delle Fontanacce which, in turn, is a right hand-side tributary of Rio Perticara.

The latter shows a SSE-NNW trend whereas the tributaries of the Torrent Tagliole have a SW-NE direction.

In the study area there are numerous springs, (e.g. Fonte Acqua Fredda, Fonte Ricca, Fonte Rondinara, Sorgente delle Fontanacce). They are located at the boundary between moraine deposits and the sandstones of the Macigno Formation. The latter is characterised by a lower permeability than the overlying deposits. In the summer, the flow rate of these springs is extremely low; usually less than 1 l/s due to the small feeding area of their catchments (Franchini, 1996).

The action of surface running waters is evident on slopes affected by rill wash, gullies, alluvial and colluvial fans, fluvioglacial and palustrine deposits and by waterfalls, V-shaped valleys and gorges found along the Torrent Tagliole tributaries.

The sandstones of the Macigno Formation are exposed in the upper Tagliole Valley showing a NNE trend monocline attitude, dipping 20° (fig. 3).

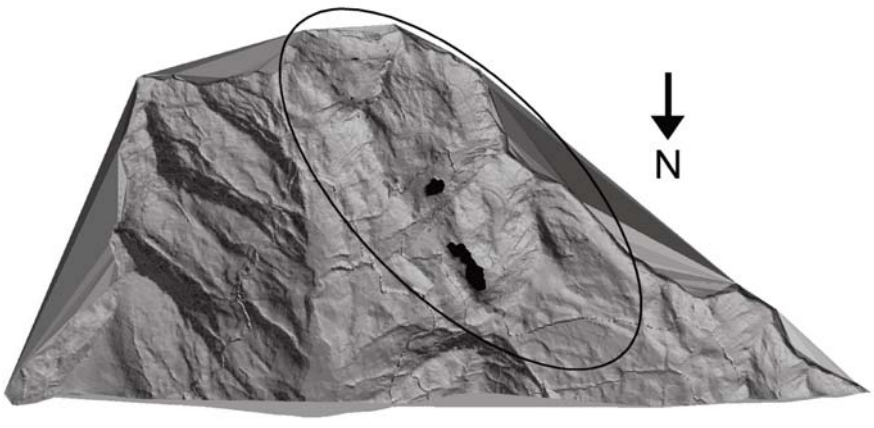

Fig. 2 – Digital Elevation Model (DEM) of the upper part of the Tagliole Valley (after Castaldini, 2003). On the left hand-side of the valley, on the northern slopes of Mts. Rondinaio (1964 m a.s.l.) and Giovo (1991 m), two well preserved twin glacial cirques have been modelled in the Macigno sandstones. At the bottom of the cirques, Lake Santo (1501 m), with its typical "bean-shaped" form, and Lake Baccio (1554 m), a sub-circular impoundment, are of particular evidence. Inside the circle, the study area.
– *Modello digitale del terreno della parte superiore della Valle delle Tagliole (da Castaldini, 2003). Sulla parte sinistra della valle, sui versanti settentrionali dei monti* Rondinaio *(1.964 m s.l.m.) e Giovo (1991 m), sono evidenti due coppie di circhi glaciali ben conservati modellati nelle arenarie della Formazione del Macigno. Sul fondo dei circhi, sono evidenti il L. Santo (1501 m), con la sua tipica forma a "fagiolo", e il L. Baccio (1554 m), a forma sub-circolare. Nel cerchio l'area di studio.*

Fig. 3 – The north-eastern cirque of Mt. Rondinaio shaped in arenaceous rock types of the Macigno Formation (Mid-Late Oligocene - Early Miocene?) showing a NNE trend monocline attitude, dipping 20°.
- Il circo nord-orientale del M. Rondinaio modellato nelle rocce arenacee del Macigno (Oligocene medio/superiore-Miocene inferiore?), che mostrano un'inclinazione a monoclinale verso NNE sui 20°.

The influence of the structural characteristics on slope morphology is relevant in all the study area where structural scarps are found and in the lower part of the northern slopes of Mts. Rondinaio and Giovo, where the slope inclination coincides with that of the strata, thus corresponding to structural surfaces. In addition, the higher erodibility of the clayey and silty intercalations determined the modelling of steps and reverse slopes upstream of which water-stagnation depressions and ponds were formed, afterwards filled by palustrine deposits. Also the tract of crests and watersheds have been considered as structural forms.

Faults and fractures are developed by morphological features such as alignments of trenches, saddles and altimetric discontinuities of ridges.

The head of the valley lies within the wide glacial cirques of Mts. Rondinaio and Giovo which are the most significant peaks found in the valley.

Trenches and reverse slopes occur in the upper portions of the north-western cirques of Mt. Rondinaio and Mt. Giovo. Trenches and reverse slopes were considered, for the first time, as the surface features of inactive rock slides which partially remodelled the edge of the cirques.

The favourable causes for triggering these rock slides might be:

i) Structural factors: the movements took place along layer joints, which correspond to lithological discontinuities (alternance of sandstones and pelites) or along the slope direction which coincides with the bedding of the Macigno Formation.

ii) Meteorological conditions: rainfall and water from snowmelt may lubricate the Macigno pelitic layers.

iii) Deglaciation: the withdrawal and final disappearance of glaciers, after the ice period corresponding to the Alpine Würm glaciation, determined a debutressing of the slopes which reacted in order to re-establish their pristine equilibrium conditions.

iv) High seismic activity: it is well documented by several earthquakes occurring in historical times in this sector of the Northern Apennines (e.g. BOSCHI *et alii*, 2000). Furthermore, the area investigated is next to Garfagnana, one of the most seismic areas of the whole Northern Apennines. In this context, the X degree M.C.S. scale earthquake which struck Garfagnana and Lunigiana on 7th September 1920 and the other ones exceeding the VII-VIII degree (1481, 1767, 1837, 1939) should be mentioned (see CASTALDINI *et alii*, 2002a).

Cirques and structural scarps show sheer, subvertical slopes which have undergone slope, cryogenic and running water processes. These scarps are therefore covered, in their lower part, by active or inactive scree slopes with talus cones and debris flow deposits (fig. 4). Many gullies developed along fracture lines and on these deposits. During the winter season these tracks are utilised also by avalanches which, in any case, do not leave significant traces in the landscape. In the lower part of the gullies, debris flow deposits and colluvial fans are found.

Rock steps and overdeepened hollows modelled by glaciers and filled by palustrine and/or lacustrine deposits, are found inside the cirques. Vast glacial deposits and numerous moraine ridges and arcs also occur at various altitudes, at the bottom of the cirques (fig. 5). They bear witness to the discontinuity of the glaciers' withdrawal, which occurred through some pause phases, after their Last Glacial Maximum expansion, when a glacial tongue occupied all the valley. Moraine deposits consist of heterometric clasts, locally very large boulders, with abundant matrix without depositional structures. Due to the barrage of runoff waters, the stadial moraine apparatuses have determined the formation of the perennial Lakes Santo (1501 m), Baccio (1554 m) and Turchino

Fig. 4 – Debris accumulation at the foot of the north-western slope of Mt. Rondinaio.
– Detriti al piede del versante nord-occidentale del M. Rondinaio.

Fig. 5 – Panoramic view of morainic arc and Lake Torbido (which is dry because it is an ephemeral lake) at the upper part of the north-eastern cirque of Mt. Rondinaio.
– Panoramica dell'arco morenico e del Lago Torbido (senz'acqua in quanto temporaneo) nella parte superiore del circo glaciale nord-orientale del M. Rondinaio.

(1613 m), plus other small lacustrine depressions which are now completely filled by palustrine deposits.

Lake Santo, with its typical "bean-shaped" form, is the largest lacustrine basin of the whole Modena Apennines; it covers an area of 58,100 m^2, a perimeter of 1259 m and a length of 550 m. Its maximum depth varies from 15 to 20 m. The lake occupies the bottom of the north-eastern cirque hollow of Mt. Giovo. The rocky threshold which contains the lake downstream is covered by moraine deposits up to 10 m thick. The glacial landscape is typical because of presence of erratic boulders and *roches moutonnées* (found near the southern sector of the lake). This lacustrine basin stretches in a NNW-SSE direction and was formed on a tectonic discontinuity. The origin of Lake Santo can therefore be considered as complex (fig. 6).

Lake Baccio is a shallow, sub-circular small lake: its diameter is about 200 m with a perimeter of about 500 m. The origin of the lake is clearly glacial since it is found at the bottom of the wide north-western cirque of Mt. Rondinaio and is barred downstream by a moraine arc cut through by its emissary stream. The shores are occupied by marshy vegetation. In its upstream part, a lacustrine delta is found. At the end of the 1980s a concrete dam was built to prevent the depletion of this small impoundment by the emissary stream.

Inside the glacial cirque on the north-eastern slope of Mt. Rondinaio, two small glacial lakes are found: Lake Torbido and Lake Turchino. Lake Torbido (1675 m) occupies a small glacial overdeepened hollow. Its shallowness and scarce water feeding condition the lake's flow regime which during the summer is often completely dry (fig. 5). Lake Turchino is a sub-circular perennial small impoundment some 1,5 m deep. It is dammed by a small moraine ridge, downstream of which a rocky threshold with *roches moutonnées* isolates an area with palustrine deposits. It is fed by small underground springs which confer it the characteristic of a permanent impoundment.

Inactive cryogenetic landforms and deposits are present, such as: several block fields present in many places in the upper part of the slopes, a block stream located inside the north-eastern cirque of Mt. Rondinaio and a well-preserved rock glacier found at the bottom of the north-western

Fig. 6 – Panoramic view of Lake Santo, the largest lacustrine basin of the Apennines of Modena. Its origin is considered complex: tectonic and glacial.
– Panoramica del Lago Santo, il bacino lacustre più esteso dell'Appennino modenese. È di origine complessa: tettonica e glaciale.

cirque of Mt. Giovo (fig. 7). This rock glacier (recognised for the first time by PANIZZA, 1992) is the only one in the whole study area. Therefore, these kinds of landforms are less numerous than shown by ALAGNA *et alii* (1987) and MAZZA & PANIZZA (1988).

There are no detailed studies on the snowline in the Tagliole Valley. Nevertheless, investigations conducted by CASTALDINI *et alii* (1998) in the adjacent Rio delle Pozze Valley by applying the method by HÖEFER (1922), produced the following results.

During the Last Glacial Maximum the snowline was about 1480 m a.s.l. Two stadial phases were recognised, in agreement with FEDERICI (1979) AND FEDERICI & TELLINI (1983). Two withdrawal stages were identified for the first phase (1st Apennine stage corresponding to Dryas I), with snowline at altitudes of 1611 and 1663 m, respectively.

Also for the second Apennine stage (or cirque stage corresponding to Dryas II) two withdrawal stages were identified, with snowline at altitudes of 1770 and 1836 m, respectively.

Finally, contrary to other valleys of the Apen-

Fig. 7 – The rock glacier at the bottom of the north-western cirque of Mt. Giovo.
– Il rock glacier sul fondo del circo nord-occidentale del M. Giovo.

nines, the Tagliole Valley has not undergone intense anthropogenetic practices Therefore the forms due to man's activity are irrelevant; in fact the only anthropogenetic feature is a parking area for tourists near the eastern side of Lake Santo.

5.2. – Geo-Tourist Map of the Upper Tagliole Valley

A geo-tourist map is a thematic map which combines geological-geomorphological data with basic tourist information. The geo-tourist map here illustrated was derived from the geomorphological map, with appropriate simplifications and integrations.

The goal was to make a map which could be easy to read for a tourist of average education. Since the readability of a map depends essentially on the simplicity of the symbols used (Papotti, 2002), we deliberately avoided to elaborate a legend with all information, which would have implied a long list of symbols. Considering that the more symbols are added the more is lost in clarity, the symbols were limited to the essential ones. The legend consists of two clearly distinct categories one with symbols representing the geomorphological characteristics and a second showing symbols concerning to tourist information.

As regards the 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, graphically pleasing symbols with short captions, avoiding specialised terminology (as it was used, for example, by Regione Emilia-Romagna, 2002; Angelini *et alii*, 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, glacial landforms and deposits, rock-glaciers, ridges, saddles); ii) the distinction of age and activity for landforms and deposits was eliminated; iii) faults/fractures were cancelled in the geomorphological map, because they are not easily identifiable in the field; iv) the less representative forms and the most difficult to recognise were eliminated (e.g. structural surfaces, slopes affected by rill wash, V-shaped valleys, fans and cones, reverse slopes); v) the various types of deposits were simplified: single grouping for moraine deposits, deposits due to superficial waters and for deposits of various origin (which includes gravitational and cryogenetic deposits); 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. They include: i) logistic information such as parking places, picnic areas, refuges, information points; ii) general information (such as footpaths, itineraries recommended by the Park, chapels, historical sites, rock sculptures, crucifixes on mountain peaks and meteorological stations).

Most of the tourism facilities (five refuges and two picnic areas) are located near Lake Santo and are easy to reach from the parking place (fig. 8).

This setting have facilitated the fruition of the study area which was visited by an average of 50.000 people during the summer season over the past years. The Upper Tagliole Valley offers many opportunities for hikers since the area is characterised by eight footpaths managed by the Italian Alpine Club (C.A.I.). Among them, two thematic Park itineraries are recommended in the map. One is a geomorphological route focusing on the land-

Fig. 8 – Tourists near Vittoria Refuge, located at the southern sector of the Lake Santo.
– Turisti presso il Rifugio Vittoria, ubicato nella parte meridionale del Lago Santo.

forms created by the glaciers which occupied the Tagliole Valley some 10.000 years ago ("In the tracks of glaciers"). The other route runs along two stretches of the ancient "Via dei Remi", a road utilised in the 18th century for the timber transport to Pisa, where the material was used for shipbuilding. The historical site, "Campi di Annibale", is located in the north-western sector of the study area. This is a rather flat area stretching over sandstone layers (corresponding to a structural surface) which, according to a legend, was used by Hannibal as a military camp.

6. – FINAL REMARKS

The study here illustrated was finalised with the implementation of a geomorphological map and a geo-tourist map of the upper part of the Tagliole Valley at the 1:10.000 scale.

The geomorphological map allows an updated and more detailed knowledge of the geomorphological features found in this sector of the Modena Apennines.

For instance, rock slide processes which have locally re-modelled the edges of the north-western cirques of Mts. Rondinaio and Giovo, were identified for the first time. Moreover, the mapping of glacial and cryogenetic landforms and deposits was revised.

The geomorphological map is common within the framework of geomorphological studies, but the geo-tourist map is an original document preceded only by another example (Castaldini *et alii,* 2005b) at least in Italy. The aim 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 and significance of its symbols, the legend was subdivided into two clearly distinct sectors; the first sector shows the symbols representing the geomorphological characteristics, whereas the second shows the symbols regarding tourist information.

The geomorphological and geo-tourist maps were implemented using the 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 geo-tourist map is the cartographic document characterising the tourist-environmental map of the Upper Tagliole Valley (Castaldini *et alii,* 2005a). This is a pocket foldable map printed on both sides with illustration notes both in English and Italian. In addition, the tourist-environmental map contains a synoptic description of the geological, geomorphological, botanical and zoological aspects, accompanied by photographs and information on excursion itineraries, visitor centres, norms of correct behaviour, refuges and, finally, cultural and tourism attractions in the region. The tourist-environmental map is part of the initiatives taken by the Frignano Park for improving the knowledge, utilisation and appraisal of the environment in a sector of its protected areas.

Therefore, the documents described were produced to meet the ever-growing educational needs of public boards and contribute to a transfer of information from scientific research to possible users and local communities.

In conclusion, these studies show how geomorphological investigations can effectively contribute to the production of maps which can be utilised in the field for environmental tourism.

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