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GEOMORPHOLOGICAL FEATURES OF THE BRATICA VALLEY (NORTHERN APENNINES, ITALY)

ABSTRACT: CHELLI A. & TELLINI C., *Geomorphological features of the Bratica Valley (Northern Apennines, Italy)*. (IT ISSN 0391-9838, 2002).

The geomorphological survey of the valley of the River Bratica, the main affluent of the River Parma, has been carried out with the aim of improving the knowledge of the geomorphological development of the eastern part of the high Apennines of Parma section.

During the survey all the processes responsible for the geomorphic evolution of the valley have been considered, with particular attention to those due to the glacial, periglacial and slope processes.

The high part of the valley is shaped mainly from the glacial and periglacial processes, active during Middle and Upper Pleistocene. The study has highlighted the landforms due to two distinct glacial phases. Evidence of the most ancient one, called Mt. Navert Phase (Middle Pleistocene), is to be found in glacial deposits containing clasts of Macigno located at Mt. Navert-Pian del Freddo, whilst for the second one, called Parma Valley Phase, corresponding to the Last Glacial Maximum (LGM) of the Alps, in the glacial deposits and moraine ridges surrounding the Mt. Navert-Mt. Quadro area.

Equally important is the morphogenesis due to frost action and nivation. Remains of gelifluction deposits (e.g. Lago di Corniglio) and nivation hollows filled by deposits made of different sized clasts (Groppo Fosco-Mt. Quadro) are signalled. The chronology for these landforms and deposits is analogous to that of the glacial phases.

The medium and lower part of the valley has been shaped mostly by slope processes with evidence of large complex landslides, sometimes involving entire slopes.

Some landslides are active and many others are dormant; the morphologic characteristics of latter suggest that their evolution is very ancient: it began in the periods of climatic deterioration of the Upper Pleistocene and started again during those of the Holocene. In fact the processes active during these periods led to the physical-mechanical weathering of the rocks, thus the instability of the slopes.

Today many dormant landslides have become active again, above all during intense and prolonged autumnal rainfall events.

KEY WORDS: Geomorphological mapping, Glacial and periglacial landforms, Landslides, Northern Apennines, Italy.

RIASSUNTO: CHELLI A. & TELLINI C., *Caratteri geomorfologici della Val Bratica (Appennino settentrionale, Italia)*. (IT ISSN 0391-9838, 2002).

È stato compiuto il rilevamento geomorfologico della valle del Torrente Bratica, il principale affluente di destra del Torrente Parma, con lo scopo di implementare il quadro dell'evoluzione geomorfologica del settore orientale dell'alto Appennino parmense. Nel corso del lavoro sono stati esaminati tutti i domini morfogenetici con particolare riguardo verso quelli riferibili alla morfogenesi glaciale, periglaciale e gravitativa.

Il substrato della Val Bratica è costituito dai terreni appartenenti all'Unità Ligure del Flysch di M. Caio e da quelli delle Unità Subliguri di Groppo Sovrano e di Canetolo ad essa geometricamente sottostanti. Le differenze di permeabilità ed erodibilità tra i litotipi a prevalente composizione calcarea e arenacea rispetto a quelli a dominante argillitico-argillosa hanno guidato, in alcuni casi in modo vistoso, l'azione dei processi erosivi.

L'alta valle è risultata modellata prevalentemente dai processi glaciali e periglaciali che hanno agito nell'area nel corso del Pleistocene medio e superiore. Sono stati individuati depositi e cordoni morenici che hanno permesso di ricostruire l'evoluzione del glacialismo della valle. Essa è stata interessata da almeno due fasi di espansione glaciale: la prima testimoniata da depositi glaciali e lembi di questi, alcuni dei quali attualmente in posizione di inversione del rilievo, come la coltre a clasti di Macigno di M. Navert-Pian del Freddo, e la seconda marcata dalla presenza sia di depositi sia di cordoni morenici distribuiti sui versanti che degradano tutt'attorno alla dorsale M. Navert-M. Quadro. La prima espansione glaciale, per la quale viene proposto il nome di Fase M. Navert per il contesto geomorfologico dell'Appennino settentrionale, è stata attribuita, in mancanza di datazioni assolute cui fare riferimento, alla fase di clima freddo corrispondente alla glaciazione rissiana delle Alpi, in accordo con gli Autori che in precedenza si sono occupati del glacialismo dell'Appennino settentrionale e della limitrofa Val Parma.

Per l'espansione glaciale più recente sono stati riconosciuti due successivi stadi di stazionamento delle lingue glaciali per i quali sono stati calcolati i limiti delle nevi sulla base del metodo di Höfer. Questo ha permesso, sempre per confronto con quanto già noto per la limitrofa Val Parma, di riferire il primo stadio alla fase di massima espansione della lingua del ghiacciaio della Val Bratica, correlabile con quello di massima espansione del ghiacciaio della Val Parma (Fase Val Parma) e con il Würm

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principale delle Alpi (LGM) (20,000-16,000 anni B.P.), e il secondo ad una fase stadiale verificatasi nel corso del progressivo ritiro del ghiacciaio stesso e confrontabile con il I Stadio appenninico della Val Parma, verosimilmente riconducibile al periodo freddo dell'Oldest Dryas.

In posizione marginale rispetto alle morfologie glaciali sono state individuate forme sia erosive sia di deposito dovute alla morfogenesi crionivale. Si tratta di conche marcate da nette scarpate a pendenza variabile riempite di depositi con tessitura dai blocchi ai limi e lembi di depositi, di estensione anche considerevole, con le medesime caratteristiche tessiturali dei precedenti, che si trovano adagiati sui versanti a sigillarne una morfologia attualmente completamente scomparsa. Anche per queste forme, come per quelle glaciali, è stato possibile individuarne almeno due generazioni. Una prima più recente, le cui testimonianze sono presenti in corrispondenza dell'alta valle del Torrente Bratica, correlabile con il periodo freddo della Fase Val Parma e una seconda testimoniata dalla coltre detritica costituita da blocchi di Flysch di M. Caio e materiale pelitico posta a Sud dell'abitato di Lago di Corniglio. Quest'ultima è stata riferita, sulla base di considerazioni legate all'evoluzione dei versanti all'interno della Val Parma, al periodo freddo della Fase M. Navert o ipoteticamente ad un'altra ad essa precedente.

In contrapposizione con l'alta valle la parte medio-inferiore della Val Bratica è contraddistinta dalla morfogenesi gravitativa, con un notevole numero di movimenti franosi molti dei quali di dimensioni veramente imponenti. Riferibili a tipologie semplici, principalmente scivolamenti rotazionali e/o roto-traslativi, o complesse, scivolamenti che evolvono in colamenti della massa spostata, si presentano come accumuli costituiti da blocchi immersi in una matrice pelitica e in alcuni casi come porzioni intere di versante traslate in blocco verso l'asse vallivo. Essi sono interessati da numerose riattivazioni che si verificano prevalentemente in stretta connessione con eventi di pioggia intensi e prolungati molto comuni in questa parte dell'Appennino settentrionale soprattutto durante il periodo autunnale, ultimo in ordine cronologico quello del Novembre 2000. Anche nell'ambito di queste forme ne sono state rinvenute alcune manifestamente inattive e poste in situazioni morfologiche che testimoniano come l'origine dell'evoluzione gravitativa dei versanti di questa parte della catena appenninica debba essere ricercata indietro nel tempo e probabilmente in corrispondenza dei periodi di deterioramento del clima pleistocenici e olocenici nel corso dei quali si verificarono processi che favorirono lo scadimento delle caratteristiche fisico meccaniche dei materiali fino al raggiungimento di condizioni di instabilità.

TERMINI CHIAVE: Carta geomorfologica, Forme glaciali e periglaciali, Frane, Appennino settentrionale.

INTRODUCTION

The geomorphological map of the River Bratica Valley was drawn with the aim of widening the already acquired knowledge on the high valleys of the River Cedra (GNGFG, 1988) and the River Parma (Federici & Tellini, 1983) and improving the knowledge of the geomorphological evolution of the eastern part of the high Apennines of the Parma section.

The flat top of Mt. Navert, between the valleys of the River Parma and the River Bratica, is attributable to a till of an age which preceded that of the last glacial maximum of the Apennines, and is probably related to the Riss Cold Stage of the Alps (Federici, 1977; 1980; Federici & Tellini, 1983); it is therefore clear that the area studied offers a picture of the geomorphological evolution of this part of the Northern Apennines starting from the Middle Pleistocene.

The geomorphological survey was extended to some areas surrounding the Bratica Valley, i.e. the high part of the western slope of the ridge Mt. Navert-Mt. Quadro and the slope where the large Corniglio landslide lies. The re-examination of these two areas (investigated by Federici & Tellini (1983), and by Pellegrini (1996), Larini & *alii* (1997; 2001) and Gottardi & *alii* (1998), respectively), has supplied new evidence closely connected with the Late Pleistocene geomorphological evolution of the high River Parma Valley, allowing to make interesting paleogeographic considerations.

GENERAL FRAMEWORK

The valley of the River Bratica is N-S oriented and is shaped starting from Mt. Navert (1,653 m), the highest peak of the area studied. It is long and narrow in shape, i.e. 10.4 km length by 4.9 km maximum width, covering a surface of 31.6 km^2. The shape of the high part of the valley is asymmetric up to the villages of Riana and Casarola and becomes progressively wide and symmetric downvalley.

The Bratica Valley is delimited, to the W, by the divide which it shares with the Parma Valley, marked by peaks above 1,300 m (Mt. Navert, Groppo Fosco, Mt. Quadro, Mt. Aguzzo). It is separated from the River Cedra Valley, to S-E, by the ridge from Mt. Navert up to Punta Fegni (1,485 m) (fig. 1).

The climatic conditions of the area studied can be derived from the values of the temperatures and rainfalls recorded at the climate stations of Ballone (825 m) and Casarola (1,000 m) and at those of Marra Centrale (635 m), Bosco di Corniglio (784 m) and Lagdei (1,245 m) placed in the neighbouring Parma Valley (GNGFG, 1988; Rossetti, 1975).

The total annual rainfall values are conditioned by the orographic and geographic features and by the N-S direction of the valley. The maximum value, 2,500 mm, is reached in correspondence of Mt. Navert and the minimum, 1,100 mm, at the confluence of the River Bratica and the River Parma, at 525 m a.s.l.

The distribution of the mean monthly rainfall values is homogenous within the whole basin. There are two maxima, the first in November (Casarola 255 mm; Ballone 142 mm; Bosco di Corniglio 288 mm; Lagdei 432 mm) and the second in spring, in March or May (Casarola 157 mm; Ballone 83 mm; Bosco di Corniglio 146 mm; Lagdei 160 mm), and two minima, one in January and the main one in July (Casarola 81 mm; Ballone 40 mm; Bosco di Corniglio 55 mm; Lagdei 86 mm). The pluviometric regime is of sublittoral Appennines type. Only the head of the Bratica Valley shows a slightly different pluviometric regime. In fact this area is characterized by mean monthly rainfall values which are very high in autumn, either for orographic reasons or for the contribution supplied from snowfalls.

Frequently intense and concentrated rainfall events mainly occur in the autumn, when rainfalls can amount to a half or a third of the total annual quantity in a few days. For example 1,070 mm were recorded at Corniglio, in the period between September and the middle of November 1994 (700 mm in the month of September). This event was the triggering factor of the reactivation of the Corniglio landslide in the Autumn-Winter 1994-95.

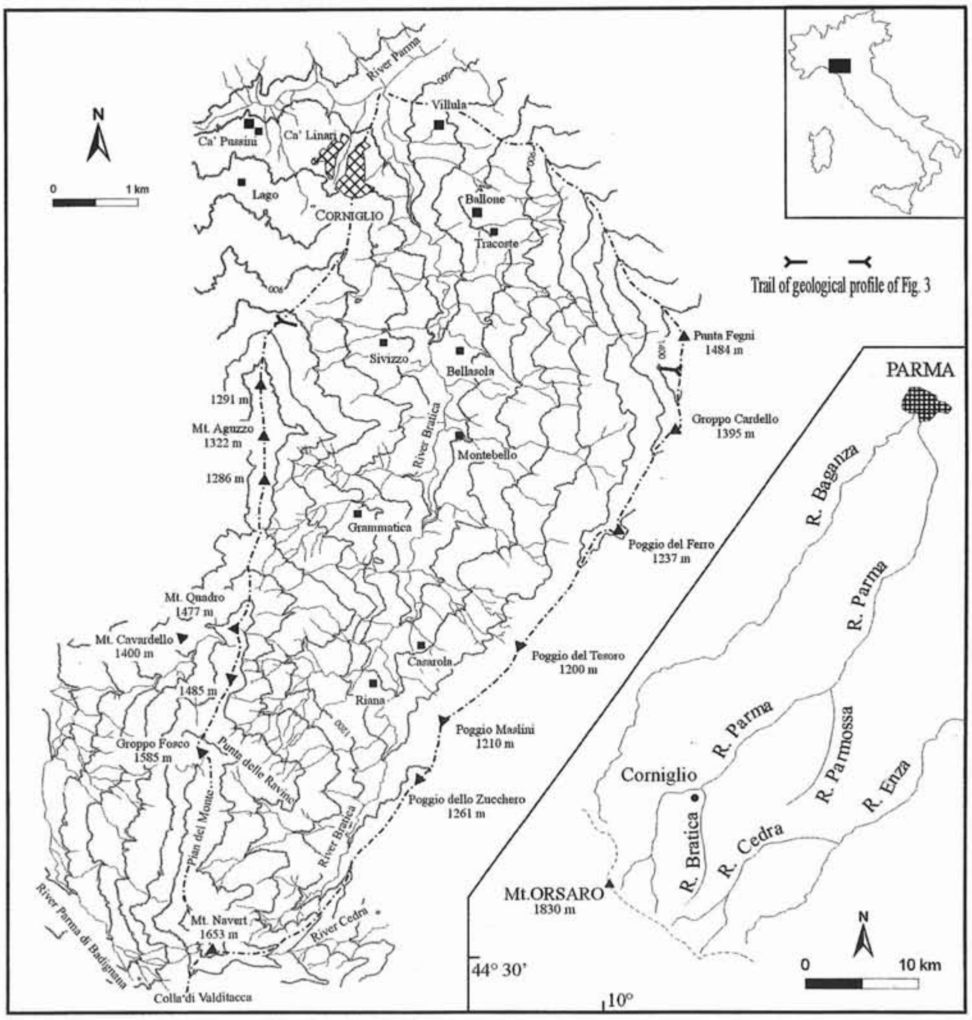

FIG. 1 - Geographical sketch map of the Bratica Valley. Here are shown the main divide and the channel network of the basin.

The snowfalls contribute to the total annual precipitation too. They vary a lot from one year to the next (Zanella, 1978) and take place in the period from October to May, but are mainly concentrated from December to March. The mean annual value of the snowfalls, mesured at the climate station of Marra Centrale, is equal to 138 cm.

The height of the snow cover is maximum in the January-February period (e.g. 70 cm at Lagdei, Parma Valley). The permanence of the snow on the ground is directly dependent upon the altitude. In fact the value of this parameter is maximum at the higher part of the basin, where 180 days with snow covering the ground have been recorded. This value decreases progressively with the altitude, reaching 60 days with snow covering the ground at the confluence between River Bratica and River Parma.

As for the air temperature, the mean monthly values decrease with the altitude. The area studied is comprised between the mean annual isotherm of 7 °C, arranged approximately according to the direction of the main divide of the Apennines range (NW-SE), and that of 11 °C, at the confluence River Bratica-River Parma. From a geomorphological point of view and above all with reference to the physical weathering of the rocks, the air temperature assumes a particular meaning with regard to the freeze-thaw cycles. These occur in the period from October to May, with a maximum concencentration of days with at least one freeze-thaw cycle in December (20 days) and January (23 days), for a total amount of 93 days in a year.

GEOLOGICAL DATA

The geological and structural setting of the area is determined by a broad recumbent syncline whose normal flank is visible in correspondence of Mt. Caio and the overturned flank on the ridge of Mt. Cervellino, northwards of the area studied, on the divide between the River Parma and River Baganza valleys (Elter & Marroni, 1991).

The thrust units involved in this syncline are, from top to bottom, the Flysch of Mt. Caio Unit, belonging to External Ligurian Domain, and the Groppo Sovrano and Canetolo units, belonging to Subligurian Domain (Vescovi & *alii*, 1998) (fig. 2).

The Flysch of Mt. Caio Unit is here represented, from the bottom to the top, by two formations. The Argille a blocchi Formation (Upper Cretaceous), chaotic in structure, is formed by shale with clast of calclutites and calcarenites. It shows variable thickness, from a few tens of metres up to completely lack for shear zones. It outcrops in the surroundings of Grammatica above all on the left side of the valley, where the best outcrop is near Passo di Zibana (1,252 m). On the Argille a blocchi Formation there is the Flysch of Mt. Caio one (Upper Campanian-Maastrichtian), which is extremely thick (1,500 m thick in correspondence of Mt. Caio). It is constituted of calcareous-marly turbidites, arranged in layers from medium to thick, interbedded with thin pelitic layers and marly clays. At the ridge Mt. Navert-Mt. Aguzzo, the flysch sequences form broad synclines linked together by close anticlines prone to overturning.

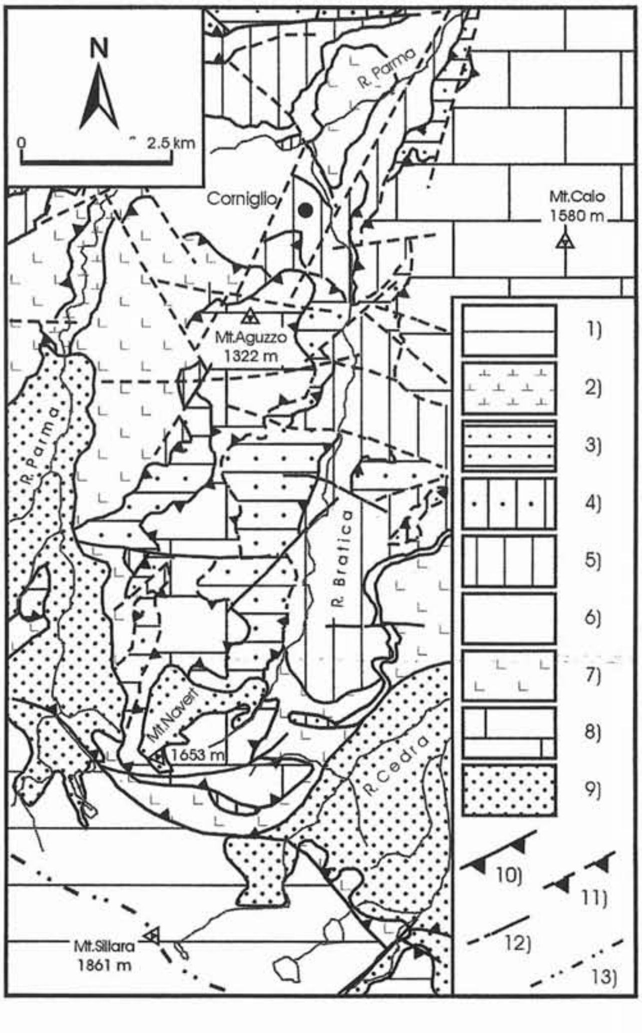

FIG. 2 - Tectonic sketch map of the Bratica Valley and surrounding area. Tuscan Nappe: 1) Macigno. Cervarola Nappe: 2) Marne di Marra. Subligurian Nappe: 3) Groppo Sovrano Unit; Canetolo Unit: 4) Petrignacola Subunit and Bratica Subunit represented by 5) Arenarie di Ponte Bratica, 6) *Mélange* di Lago and 7) Argille e calcari di Canetolo. Ligurian Nappe: 8) Mt. Caio Unit. 9) glacial deposit; 10) overthrust; 11) uncertain overthrust; 12) fault; 13) divide of the Apennines range (redrawn from Vescovi, 1998).

The tectonic contact between the Flysch of Mt. Caio and the underlying Subligurian units is marked by well developed tectonic breccias and shear zones. Immediately below this contact outcrops the Groppo Sovrano Unit. It is made by Argilliti di Riana Formation constituted by black shales with interbedded reddish siliceous siltites and monogenic breccias containing chlorite schist clasts (Cerrina Feroni & *alii*, 1990). In the formation are also present turbiditic thin sequences constituted by fine sandstones and marls like-slate, arranged in layers from medium to thin. The thickness of the formation is at least 50 m. Above it is the Flysch di Grammatica Formation (Ypresian, Lower Eocene). It is formed by sequences of multicoloured silty marly clays alternating with fine grey-black calcarenites, about 25 m thick. This formation is followed by the Arenarie di Groppo Sovrano Formation (Ypresian), about 90 m thick. It is constituted by a turbiditic sequence made of grey sandstones alternating with thin pelitic layers. Thin micritic limestones and thin flint arenaceous layers are interbedded with the sandstones. Above it there is an arenaceous-marly flysch, the Flysch di Rio Canalaccio (Ypresian), about 20 m thick. The Groppo Sovrano Unit ends with the *Mélange* di Rio Rodichiasso (Lutetian, Middle Eocene) constituted by clays, marly clays and pieces of Flysch di Rio Canalaccio, Flysch di Grammatica and Arenarie di Ostia. The formation presents low-angle shear surfaces and deformation fabric formed during diagenesis processes (Vescovi & *alii*, 1998).

The Canetolo Unit was divided by Vescovi (1998) into two superimposed tectonic subunits, named Petrignacola and Bratica.

The Bratica Subunit is formed, starting from the bottom, by the Arenarie di Ostia (Coniacian-Santonian). It is a turbiditic sequence made of thin layers of fine sandstones alternating with siltstones and pelites. Then there are the Calcari di Groppo del Vescovo (Lower Eocene). They are composed of turbiditic sequences of micritic limestones, whose thickness varies from thick to very thick, with thin layers of argillites and thick marly layers. The formation is about 100 m thick. Immediately above the Calcari di Groppo del Vescovo there is a clayey-calcareous *mélange* (Paleocene-Upper Oligocene) (Vescovi & *alii*, 1998) constituted by shales that contain calcareous-marly turbiditic layers. The tectonic subunit ends with the formation of Arenarie di Ponte Bratica (Oligocene). It is formed by turbiditic layers, whose thickness is medium or thin, alternating with clayey-marly layers. Vescovi & *alii* (1998) have shown the presence of thick layers of coarse-medium sandstones and breccias with clayey matrix in the lower part of the formation.

The Petrignacola Subunit is constituted, from the bottom to the top, by Argille e calcari del Passo di Ticchiano and Arenarie di Petrignacola (Lower Oligocene) formations. The former is constituted by few metres of calcilutites and clayey-marly layers, and, in the upper part, by micritic limestones with thin layers of turbiditic sandstones. The latter, about 50 m thick, is formed by green and grey volcanoclastic sandstones, sometimes with conglomerate, arranged in coarse and thick layers interbedded with thin siltstone layers.

Within the Canetolo Unit there is also a chaotic body, i.e. the *Mélange* di Lago (Vescovi, 1998). It is formed by blackish clay containing calcareuos, marly and sandy layers. Within the *mélange* there are tectonic slices probably coming from Argille e Calcari di Groppo del Vescovo and Arenarie di Petrignacola formations. The origin of this chaotic body seems connected to syntectonic processes due to shortening of the sedimentary basin of the Arenarie di Ponte Bratica.

STRUCTURAL GEOMORPHOLOGY

In the area studied there are phenomena of selective erosion, which are due to the different behaviour of the mainly shaly rocks from that of the calcareous and sandy flysch formations during erosive processes. For example the ridges that divide the Bratica Valley from the high Parma Valley, westwards, and from the Cedra Valley, eastwards, are shaped in the flysch rocks whereas the quaternary fluvial/glacial downcutting of the valley occured mainly in the Subligurian units, determining also the slope instability of the overlying flysch rocks.

In the areas where the Subligurian rocks outcrop, the geomorphological features are conditioned by: a) the intense comminution of the shale into millimetric slices; b) the presence of calcareous and arenaceous bodies included within the mainly shaly rocks.

Even the different hydro-geological behaviour of the outcropping rocks has had a relevant role in the geomorphological development of the valley. The contact between permeable, mainly for jointing, and impermeable rocks gives rise to many springs that favour the slope instability.

The Arenarie di Groppo Sovrano outcrop almost everywhere with subhorizontal attitude of the beds. This fact has promoted the development of very steep scarps, which break off the slopes as can be seen either between the villages of Grammatica and Riana (fig. 3) or between Mt. Quadro and Groppo Fosco, in the right-hand side of the River Parma di Badignana Valley. In this last site the general joint-block separation favours the debris falls and the presence of talus slopes.

The area studied is also characterised by fault systems (fig. 3) linked to the Plio-Pleistocene uplift of the Northern Apennines range, which was mainly realized by the strong uplift of the Macigno Formation (Tuscan Nappe) (Bernini & *alii*, 1994). This differential regional tectonic uplift determined 5 tectonic zones, arranged in NW-SE direction, with progressive decrease of the uplift rate moving towards N (Papani & Sgavetti, 1975; Schiroli, 1982). The Bratica Valley lies within the tectonic zone where the uplift was the greatest determining a high relief energy and a greater rate of the downcutting.

The faults exerted a strong conditioning on the geomorphology, promoting the development of linear morphologic features (e.g. gullies and deep small valleys) (see the Geomorphologic Map) and of large landslides lined up with them and each other. The fault situated N of the village of Sivizzo is very important in this regard. It has an E-W strike and penetrates into the crown of the large Corniglio landslide.

This fault might have had an important role in the reactivation of the landslide, promoting the seepage and the processes plasticising the underlying shales; in fact there is a spring (not present in the Geomorphological Map) within the crown of the landslide near Campo Lusini that feeds the earth flow on the right-hand flank of the landslide.

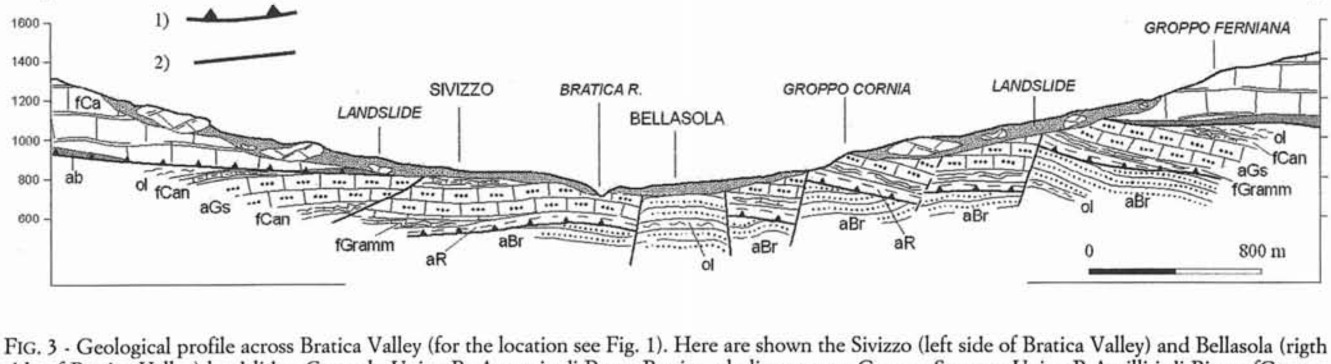

FIG. 3 - Geological profile across Bratica Valley (for the location see Fig. 1). Here are shown the Sivizzo (left side of Bratica Valley) and Bellasola (rigth side of Bratica Valley) landslides. Canetolo Unit: aBr Arenarie di Ponte Bratica, ol olistostrome; Groppo Sovrano Unit: aR Argilliti di Riana, fGramm Flysch di Grammatica, aGs Arenarie di Groppo Sovrano, fCan Flysch di Rio Canalaccio, ol olistostrome (Mélange di Rio Rodichiasso); Flysch di M. Caio Unit: ab Argille a blocchi, fCa Flysch di M. Caio; 1) overthrust; 2) fault.

RUNNING WATERS AND KARST GEOMORPHOLOGY

The drainage system of the Bratica Valley was influenced either by the glacial and postglacial landforms, on which the consequent fluvial deepening and the slope instability processes are superimposed, or the geological characteristics of the bedrock. In the higher part of the basin the drainage pattern was conditioned by the previous glacial and fluvioglacial landscape, whereas the tectonic discontinuities generally have promoted the development of streams, as is visible from the coincidence between these and faults. The results were a drainage pattern of dendritic type, in the higher part of the catchment area, and subdendritic type in the lower one (fig. 1).

In the upper parts of the slopes the gullies are the best recurrent erosional landforms due to the running waters. The more the bedrock is prone to erosion, the deeper these gullies become, gradually producing small V-shaped valleys. The recent deepening of the drainage system has given rise to very steep scarps, and is responsible for the reactivation of many landslide bodies, or portions of them, as can be seen along the road between the villages of Grammatica and Riana.

The erosive fluvial processes have had a greater effect along the River Bratica channel. The river flows for long stretches embanked in the bedrock between very steep rocky scarps or between scarps, on the one side, and the toes of dormant landslides, on the other. Where it flows on its own alluvial deposits, it cuts fluvial scarps, often more than 5 m high, which define terraces, as can be seen below the village of Montebello, where the river has deepened to the underlying bedrock.

In different sites the River Bratica erodes its bank. This mainly takes place where landslide bodies force the river onto the opposite side. Sometimes the river has had to find new flow paths, as abandoned river channels prove, e.g. a few hundred metres below the village of Bellasola.

The fluvial settling prevails in the lower part of the River Bratica, near the confluence with the River Parma. The River Bratica gives rise to alluvial deposits mainly in the occasion of the recurrent floods, as occured during the rainfall events of 28 October 1999 and in the month of November 2000.

The minor streams that drain the slopes of the Bratica Valley give rise to small alluvial fans that are dormant or inactive, as can be seen from their appearance. Only the alluvial fan at the end of Rio Lumiera, the stream which borders the right-hand flank of the Corniglio landslide, is active. In fact it is fed by the rock materials removed from the landslide body, which is still active.

On the flat top of the Mt. Navert there are some dolines (fig. 4), some of which were pointed out by Federici & Tellini (1983). They are related to the presence of the thick calcareous beds of Flysch of Mt. Caio. There are either subdendritic dolines with a flat bottom, diameter which does not exceed 15-20 m, or long hollows, 2 or 3 m deep. The origin of the latter must be referred to the presence of small faults and fractures that guide the infiltration of the running waters.

FIG. 4 - One of the small dolines located on the top of the Mt. Navert. During the rainy season these depressions fill with water giving origin to small pools.

MASS WASTING AND LANDSLIDES

The geomorphological survey has highlighted that mass wasting is the main process acting in the area studied. In detail in the whole Apennines of Parma section the percentage of the territory involved in landslides has doubled in the past twenty years. In fact the percentage of the total surface affected by landslides increased from 10.6%, at the end of the Seventies (Agnesini & *alii*, 1978), to 26.6%, at the end of the Nineties (Regione Emilia Romagna, 1999). In the Bratica Valley 42% of the catchment area is involved in landslides, either active or inactive.

As to the spread of the landslides, the Geomorphological Map allows to divide the Bratica Valley in two parts.

The high part of the catchment area shows few landslides, small in size generally affecting the glacial deposits, whilst the slopes of the middle and lower ones are affected by a great number of landslides, different in type and style of the activity, sometimes involving a large volume of rock and/or earth.

In detail the right-hand side of the Bratica Valley, between the villages of Montebello and Ballone, and the left-hand side near Sivizzo are affected by a set of large landslides with a distribution of the activity of retrogressive type; these in some cases are developed up to the divides, involving parts of the Flysch of Mt. Caio beds. They are complex landslides (i.e. rotational rock or earth slides - earth flows), as is proved by the geomorphological evidence (counterslopes containing puddles and/or palustrine deposits, hummocky terrain, etc.).

The Montebello landslide mainly involves the formation of Arenarie di Ponte Bratica. It is dormant and shows some small reactivation below the municipal road where the sandstone layers slide on the pelitic interbeds. The Bellasola landslide shows the same state of activity as the Montebello one, i.e. reactivations occurred after the damage of some check dams located across the River Bratica (rainfall/flood event in November 1994) and caused by the renewal of the undermining of the banks.

The Ballone landslide (fig. 5) is one of the largest in the area. It is a complex landslide arisen out of the tectonic contact between Ligurian and Subligurian units. Probably the landslide is very ancient and it has a peculiar morphology and position:

- the main body hangs on the valley floor, in a situation of inverted relief; it is supported by an outcrop of Arenarie di Ponte Bratica dipping in the slope;
- the surface of the landslide does not show the typical hummocky morphology but it is «regularized» showing a parabolic profile joined to the talus slopes below the main scarp;. the few sections of the landslide body show that the landslide surface is not regularized by the presence of a deposit on it (e. g. colluvium) but is the result of erosional processes;
- the flanks of the landslide have been split by reactivations that have reduced the main body forming the hanging morphology.

A reactivation of the Ballone landslide occured in the past century. On 4 May 1915 a landslide, involving flysch rocks, developed from altitude 950 m a.s.l. (for historical information from the journal «La Giovane Montagna», 8 May 1915, see Dall'Aglio, 1956; Dall'Olio, 1975). It continued to move up to the middle of the same month, destroying several houses of the village of Tracoste. It involved a total area of about $4x10^5$ m^2 and gave rise to a

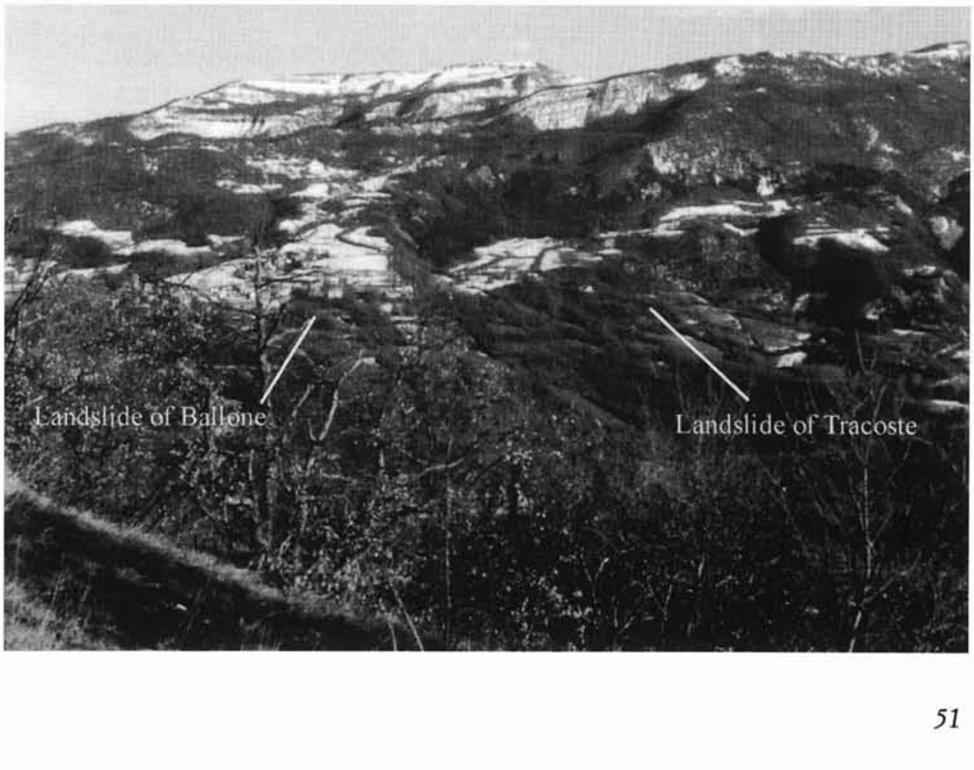

FIG. 5 - The large landslides of Ballone and Tracoste on the western slope of Mt. Caio. The central/lower part of the main body of the complex landslide of Ballone assumes the typical shape of a fan due to flow type movement.

huge counterslope in which a small lake (Lago delle Ferle) still lies.

Apart from these, there are other large landslides on the right-hand side of the valley. Some rock-block slides, involving thick beds of Flysch of Mt. Caio, move along the slope below Poggio del Ferro. Similar phenomena are present on the left-hand side of the valley too. Below the ridge between Mt. Aguzzo and Mt. Quadro large rock-block slides and complex landslides affect the slopes around the villages of Sivizzo and Grammatica. From a textural point of view the main bodies of these landslides are rich in matrix and constituted by portions mainly containing poor sorted debris and others, where the flysch rocks are moved *en masse*, maintaining a structure close to the real one but where the bed's attitude has rotated.

The Sivizzo landslide is a powerful example of ancient landslides. It has developed through different retrogressive reactivations of compound type, involving progressively the entire slope from the divide to the River Bratica. In the crown of the landslide there are deep trenches proving that the gravitative evolution of the slope is still active. A portion of the landslide body was involved in a large reactivation (fig. 6) in November 2000, when an intense rainfall event affected the River Parma basin and surrounding areas. It acted on the front of the ancient landslide and was of complex type (compound earth slide - earth flow), 450 metres wide and 400 metres long. The reactivation reached the River Bratica damming it, and giving rise to an ephemeral lake.

The Corniglio landslide is the largest active one within the area studied. It is well-known that its movements have repercussions on the southern part of the medieval village of Corniglio (700 m a.s.l.), and even on the Bratica Valley side, and that it has had a recurrent activity in the past 400 years (Larini & *alii*, 2001).

Reactivations of the entire landslide body are proved by historical documents in 1612, 1740 and 1902 A.D. Nevertheless the landslide was active in previous epochs, as is proved by a cadastral survey of the 1559 A.D., where the local placename «La Lama» (i. e. the landslide) is quoted. In summer 2001, during the last surveys carried out on the landslide, three pieces of wood were found within the most ancient part of it, i. e. La Lama. These underwent a standard radiometric analysis and the results have shown two time spans during which reactivations took place. The radiocarbon ages are 1550±50 ^{14}C yr B.P. (Beta-156622) corresponding to 1540-1320 cal yr B.P. (2σ) (Stuiver & *alii*, 1998) and 1440±50 ^{14}C yr B.P. (Beta-156623) corresponding to 1410-1280 cal yr B.P. (2σ). Both time spans, corresponding respectively to the 5th-7th centuries A.D. and 6th-7th centuries A.D., are included between 400 A.D. and 750 A.D., known as the period of climatic deterioration of the early Middle Ages, when floods and mass wasting occurred in the Po Plain and Northern Apennines range (Chelli & Tellini, 2001; Cremaschi & Gasperi, 1989; Veggiani, 1974; 1981; 1983; 1985; 1986). After a period of about one century during which the landslide was dormant, a new reactivation started in November 1994, involving the upper and central parts of its body. In 1996 the reactivation, still active nowadays, involved the entire landslide body.

Today the Corniglio landslide has considerable dimensions. It is over 3,000 m long, 1,100 m wide and the maximum depth of the surface of rupture is 120 m. The crown of the landslide lies at 1,150 m a.s.l. and its toe is at 550 m a.s.l., in proximity of the River Parma thalweg. The movements are both multiple rotational and compound slides which turn into earth flows in the upper 20 metres of the body (i.e. complex and composite landslide); the total volume is approx 200x10^6 m^3 (Larini & *alii*, 2001). On the basis of the history outlined above, the landslide has an intermittent type of activity, characterized by slow rate of movement and reactivations which occur every century. In the period 1994-1999, the total displacements of the zone of accumulation of the landslide (Ca' Linari, cf. Geomorphological Map) was nearly 50 metres, and it almost dammed up the River Parma.

Displacements of some centimetres were recorded by inclinometers placed at the ridge where the village of Corniglio lies. They are directed towards either the River Bratica Valley (NE) or the Corniglio landslide. On the western side of this ridge is a large active rotational landslide which

FIG. 6 - The crown and the head of the reactivation of the Sivizzo landslide occurred in November 2000.

FIG. 7 - The talus slope on the western side of the Groppo Fosco. It is inactive and shows ridges (marked by white lines) due to gelifluction processes.

involves, with its northern part, the village of Corniglio. The movements of this landslide are partly linked with those of the Corniglio one. Indeed the activity or quiescence of the landslide of Corniglio produce, respectively, the «dragging» or «replacement» of the rock (Arenarie di Ponte Bratica) blocks which form the landslide, determining displacements in opposite direction.

Portions of inactive landslide bodies, improperly named «paleolandslides», are present in several sites. Their presence proves that very ancient morphology is present on the slopes of the area studied. Generally these landslides are placed in morphological situations of inverted relief and do not show any connection with their source area. The village of Corniglio, which was previously believed to be built on the Arenarie di Ponte Bratica, actually lies on one of these ancient landslides. As revealed by some boreholes, it is constituted by angular clasts, coming from Arenarie di Ponte Bratica, immersed in a pelitic matrix. The landslide body is very thick, varying from 27 metres, below the centre of the village, up to 56 metres, below its southern part.

The origin of these «paleolandslides» could be referred to climate periods in which the cryogenic processes were outstanding, as during the Apennines glacial stages which in the high River Parma Valley were two: the Parma Valley Stage and the Mt. Navert Stage (par. Glacial Geomorphology). This fact is proved indirectly by the radiocarbon age 25,129±160 ^{14}C yr B.P. (Beta-151581) (Bertolini & Tellini, 2001) obtained from a wood sample found in the Carobbio landslide. Therefore this last one, located a few kilometres away towards NE from the area studied, was already active during the Last Glacial Maximum of the Northern Apennines.

PERIGLACIAL GEOMORPHOLOGY

Several authors have pointed out the presence of periglacial landforms in the Parma and Reggio Emilia section of the Apennines.

Bernini & *alii* (1978) and the Gruppo di Ricerca Geomorfologica-CNR (1982) signalled the presence of *grèzes litées* on the southern slope of Mt. Prampa and of *glacis* in the upper Secchiello Valley (River Secchia basin). The area around Pietra di Bismantova (G.S.U.E.G., 1976) shows the remains of gelifluction flows, and many others of similar origin were found by one of the authors in the Reggio Emilia section of the Apennines during researches carried out for graduation theses or surveys for the Geological Map of the Emilia-Romagna section of the Apennines.

In the Parma valley Federici & Tellini (1983) have identified vast block fields deriving from the physical weathering of the arenaceous beds of the Macigno and gelifluction lobes due to the slow movements of the soil caused by the internal presence of ice.

As to the upper Bratica Valley, different landforms have been identified on both slopes of the Groppo Fosco-Mt. Quadro ridge. These landforms are due to cryogenic and nival processes: they are cryogenic and nival hollows, characterised at the ridges by scarps which slope in varying degrees and whose upper edge is generally sharp. They all developed within the outcrops of the Flysch of Mt. Caio or sandstone rocks (Arenarie di Groppo Sovrano), which are often affected by several fractures. At the base of the scarps are deposits of debris of varying thickness, up to 10-15 metres, made up of minute debris in pelitic matrix. These deposits are all covered by thick vegetation, which testifies to their inactivity.

Unmistakable signs of rielaboration due to seasonal freezing and thawing have been found on a talus slope at the base of the scarp on the western side of Groppo Fosco (fig. 7); this talus slope is made up of sandstone blocks of very different sizes, which are covered by lichens and amongst which matrix is present. The surface of the talus slope reveals structures linked to the flow, made up of small ridges of material in blocks, arranged both longitudinally and transversely to the maximum inclination of the slope.

During the studies carried out on the large Corniglio landslide, Larini & *alii* (2001) identified another thick detritic deposit located S of the village of Lago (fig. 8). It covers an area of approx 100,000 m^2 and because it is isolated and in relief on the slope below, it can be considered as the last remain of a deposit which must have originally covered most of the slope.

The analysis of some natural profiles has highlighted that it consists of a *diamict* made up of polyhedric clasts of different sizes with sharp edges, whose diameter varies

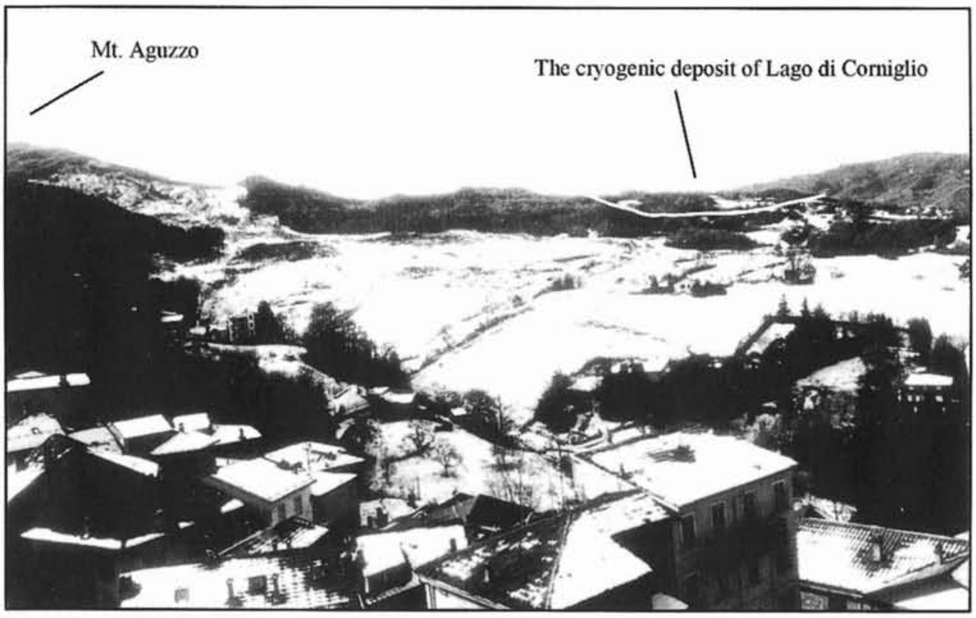

FIG. 8 - The deposit of Lago di Corniglio covers a portion of the northern slope of Mt. Aguzzo.

from a few centimetres to a metre, in pelitic matrix. The calcareous-marly composition of most blocks has been a puzzling discovery as to its geologic origin. In fact, this deposit can be considered either as regolith of the *Mélange* di Lago below, containing similar litotypes, or as a deposit caused by the physical weathering of the slopes of Mt Aguzzo, modelled in the calcareous-marly Flysch of Mt. Caio.

In order to establish the formation of origin, samples were taken from the marly fraction of some blocks and analysed with the aim of identifying their paleontologic content. The analysis revealed the presence of calcareous nannoplancton, referable to the Upper Cretaceous, and thus confirmed that they belonged to the Flysch of Mt. Caio Formation[1]. This deposit is a proof of what is left from the slope's evolution in a geomorphologic and climatic environment which was completely different from the present one. Its sedimentologic features are consistent with the ones observed in the cryogenic deposits present in the upper part of the valley, so it is likely that its origin is tied to the same processes.

GLACIAL GEOMORPHOLOGY

The presence of glacial deposits in the Northern Apennines was first reported by De Stefani (1883), who also hypothesised the glacial origin of many lakes. After these pioneering observations many authors began to investigate the glacial geomorphology, especially in the Parma section. The main reference in the older bibliography is Losacco (1949), whilst the more recent bibliography includes Federici (1977), Federici & Tellini (1983), GNGFG (1988) and Jaurand (1998). The maps which, with greater or lesser detail, show the distribution of glacial deposits include: the map by the Servizio Geologico d'Italia (Foglio 85 Castelnuovo ne' Monti, 1st ed. 1932; 2nd ed. 1968), the map by Zanzucchi (1963), the «Carta Geologica 1:100,000 della Provincia di Parma e zone limitrofe» (Istituto di Geologia di Parma, 1966), the «Carta Geomorfologica dell'alta Val Parma» by Tellini & Federici (1983) and the «Carta Geomorfologica dell'alta Val Cedra (Appennino parmense)» by Schiroli & Tellini in GNGFG (1988). The Parma valley during the glaciation is also shown in the table by B. Castiglioni in the Atlante Fisico-Economico d'Italia by Giotto Dainelli (1940).

The glacial geomorphology in the Bratica Valley characterises the valley head in the area comprised between Mt. Navert, Groppo Fosco and the confluence of Rio della Costa and the River Bratica.

The erosional landforms include glacial cirques whose edges show different states of preservation. The most developed and best preserved landforms are the ones of the cirque which opens towards E below the Punta delle Ravine and the two coalescent cirques located in the glacial deposits of Mt. Navert, orientated towards N-E. The western side of the Mt. Navert-Mt. Quadro ridge also shows cirques, including the one below Groppo Fosco. The different development of these landforms is mainly explained by the different aspect of the two sides of the ridge; the glacial morphogenesis was in fact favoured in the sides with N-E aspect.

[1] We are grateful to Dott.ssa G. Villa (Dipartimento di Scienze della Terra, Università di Parma, Italy) for the analysis of the samples and the chronostratigraphic determinations.

The situation is different as regards the erosive landforms modelled by the glacier tongues along the axes and the valley sides. The Geomorphological Map highlights the absence of scarps or counterslopes in the head of the Bratica Valley which can definitely be attributable to glacial modelling. However, these appear to be abundant on the western side of the Mt. Navert-Mt. Quadro ridge. A primary role in the modelling of these landforms was obviously carried out by the lithological-structural contrast of the rocks, but especially by the thickness of the glacier tongues, which is much smaller for the glacier of the Bratica Valley than those of the neighbouring Cedra and Parma valleys.

Glacial deposits are more or less continuously present on most of the sides of the upper valley. Mt. Navert's ridge has a thick glacial deposit, modelled like a flat relict surface; the peculiarity of this deposit was highlighted by Zaccagna (1898) and confirmed by Zanzucchi (1963). Federici (1977) then attributed it to a glaciation preceding the Last Glacial Maximum (LGM) in the Parma Valley, and the hypothesis was then confirmed by Federici & Tellini (1983). It was Demangeot (1965) who first highlighted traces of a glaciation preceding the LGM in the Abruzzi section of the Apennines.

The thesis of a double glaciation in the Apennines of Parma section is supported by mainly morphological reasons. If the deposit of Mt. Navert is referred to a concomitant overflow of the Parma Valley and the Cedra Valley glaciers (Zanzucchi, 1963), we are faced with the morphological evidence of the pass Colla di Valditacca (separation point for the two valleys) and the height of the glacial deposit itself, comprised between the 1,653 m of Mt Navert and the 1,550 m of Pian del Monte. This elevation, compared to the heights of the glacial landforms in the River Parma di Badignana Valley, leads to assume a thickness of the glacier tongue greater than 500 metres, which doesn't appear to agree with the limits of the extension of the LGM glacial deposits. Other considerations must be made:

- the deposit is made up of material attributable to the Macigno of the Tuscan Nappe, whose turbiditic beds outcrop at the main divide of the Apennines range, at approx 3 km S as the crow flies;
- there is no morphological connection between the surface of the deposit and the divide itself on the hypothetical direction of the glacier tongue, as the pass Colla di Valditacca (1,467 m) is located in between;
- S of Mt. Navert, instead of a glacial valley, the Mt. Paitino-Rocca Pumaciolo ridge is to be found; this testifies to the long morphologic evolution which has allowed the relief inversion in the Macigno;
- part of the glacial cirques in the Parma Valley Phase are modelled in the deposit of Mt Navert.

This interpretation is supported by the fact that other remains of glacial deposits, similar to Mt. Navert one as to texture and composition, but not continuous with it, have been found in several places along the ridge which reaches Mt. Verniceto (1,413 m), within the basin of the River Cedra (see the Geomorphological Map). This proves that the deposition of this glacial deposits must have taken place in a landscape whose morphology was very different from the upper basins of the rivers Parma and Cedra during the last glaciation (LGM).

At E of Mt. Navert's ridge are glacial deposits which descend the valley's sides reaching different altitudes. In the Bratica Valley the maximum extension of the glacial deposits is marked by the confluence of Rio della Costa and the River Bratica itself, at a height of about 1,185 m. They have the facies of a *diamict* made of calcareous-marly blocks of flysch and Macigno supported by sandy-silty matrix and come from the rielaboration of Mt Navert's glacial deposit. At W of the initial stretch of the River Bratica, included between the heights of 1,300 m and 1,350 m, are two small lateral moraine ridges, as reported by Federici & Tellini (1983). At the same height, some remains of glacial deposits, which had never been signalled before, have been identified on the left side of Rio della Costa.

On the two sides of the Rio Freddo Valley two other sinuous lateral moraine ridges are present; they tend to converge forming what probably was a frontal moraine ridge (cf. Geomorphological Map); they are attributable to a glacier tongue which originated from the glacial cirques below Mt. Navert and set them at a height comprised between 1,325 m and 1,470 m.

The valley at S of Punta delle Ravine is covered by a not very thick glacial deposit which shapes it into hummocks and counterslopes and was previously considered a landslide. However, a further analysis of the geomorphological situation highlighted the following elements:

- the small volume of the deposit compared to the size of the cirque above;
- the favourable aspect of the cirque, orientated towards E;
- the textural features of the deposit, similar to the glacial deposits found in the valley;
- the presence of calcareous-marly boulders, striated by the glacial erosion.

This deposit is therefore attributable to the glacial morphogenesis, and the revision can be extended to similar morphological situations, present in the secondary valleys at heights comprised between 1,500-1,400 m, where small glaciers developed presumably only during the acme of the Last Glacial Maximum.

The western side of the Mt. Navert-Mt. Quadro ridge is mostly covered by glacial deposits with thickness up to several tens of metres formed by a *diamict* of large boulders of Macigno and Flysch of Mt. Caio immersed in a silty-sandy matrix. Because of the washing away, the matrix only appears in the deeper parts of the deposits, so that the piled up boulders emerge.

Below the cirque orientated to the W in the Groppo Fosco ridge is a glacial deposit where two moraine ridges can be identified (fig. 9): one is curved and small, located at 1,495 m close to the walls of the cirque, whilst the other is long and located slightly further down, between 1,475 and 1,495 m, drawing a bigger arch which is cut by the stream which drains the hollow. The shape of these two

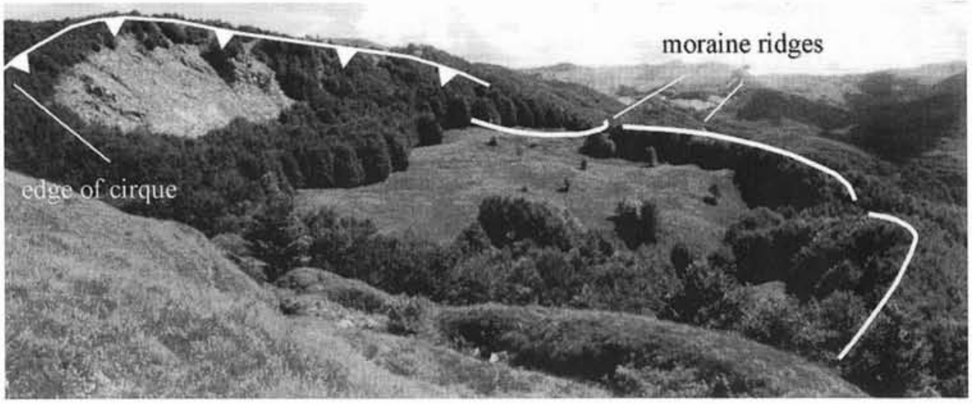

FIG. 9 - The glacial deposit of the western side of Groppo Fosco ridge.

moraine ridges leads to believe that these are two small frontal ones laid down by a small cirque glacier during variations of its front.

Two moraine ridges are to be found also along the northern side of Groppo Fosco, but the thick vegetation and their very bad state of preservation have made recognition difficult. They can be identified at 1,425 m and their front reaches 1,385 m. The moraine ridges are cut in several places by running waters and they enclose a small hollow containing a deposit which in the top part is made up of mainly silty-sandy material.

The glacial stages of the Bratica Valley

Especially because of the bad state of preservation of the glacial deposits, the reconstruction of the glacial stages which have been identified in the Bratica Valley has been a difficult task. On the basis of the authors who reconstructed the evolution of glacialism in this section of the Northern Apennines (Federici, 1977, 1979; Federici & Tellini, 1983; Jaurand, 1998; Losacco, 1949, 1982), the snow limit has been calculated with the Höfer method (1922), which derives the snow line from the arithmetic mean of the heights of the glacier front (assumed or ascertained) of the ancient glacier and the mean height of the ridges of the mountainous barrier surrounding the accumulation area.

A first stage is marked by the glacial deposits which reach the confluence of Rio della Costa and the River Bratica; the value of the snow line limit which they have provided is equivalent to 1,381 m. A second stage is represented by the frontal moraine ridge of Rio Freddo, which must have been laid down when the snow line limit reached approx 1,477 m (i.e. moved up about 96 m from the previous position).

Despite the difficulties mentioned above, these values are consistent with the geomorphological evidence. In fact, the altitude of the snow line limit attributable to the first glacial stage (1,381 m) corresponds reasonably well with the highest altitude of the lateral moraines located W of the River Bratica, both slightly above 1,350 m. In the same way, the snow line limit at 1,477 m does not appear to be different from the highest altitude of the lateral right moraine of Rio Freddo (1,470 m).

The values of the snow line limits of the glacial stages of the Bratica Valley allow us to hypothesise a relationship with the succession put forward by Federici (1979) for the Central Apennines, then applied by Federici & Tellini (1983) to glacialism in the Parma Valley. This division includes three Late Glacial stages and presumably a Post-Glacial stage, recognisable only on Gran Sasso d'Italia (Central Apennines). However, several features, particularly geographical ones, must be taken into consideration in this comparison, as they characterize the Bratica Valley in a different way from the valleys nearby as to the development of glacialism.

The accumulation area of the Bratica Valley glacier, which was located at about 3 km from the main divide of the Apennines, was much smaller than the ones of the glaciers of the Cedra and Parma valleys and it was situated at an height which is on average 100-150 m lower. On the whole these facts must have caused a smaller contribution of snowfalls from the wet air masses moving up the Tyrrhenian side of the Apennines.

Moreover the glacier, whose shape must have been intermediate between the slope glacier and the cirque glacier and whose thickness must have been limited to few tens of metres, developed on the edge of a relict surface, where the gradients of the slopes cannot have been steep.

Finally, because of its small size, the glacier likely disappeared in the early phases of the Late Glacial.

On the basis of the above considerations, it can be hypothesised that the glacial deposits located at the confluence Rio della Costa-River Bratica were laid down during the maximum glacial advance in the Bratica Valley, which corresponds to the LGM in the Parma and Cedra valleys, in what was named «Parma Valley Phase» in Pellegrini & *alii* (1998). It would actually be rather strange if an advanced phase, which in the Parma Valley brought the glacier fronts near the villages of Staiola and Polita (approx

730 a.s.l.) with a snow line limit at 1,262 m, had not left any trace in the Bratica Valley.

The glacial deposit of Rio Freddo should instead correspond to the I Late Glacial Stage of retreat on the Apennines (Federici & Tellini, 1983). Corresponding to this phase the snow line limit had risen approx 110 metres compared to the maximum glacial advance, i.e. settling at about 1,375 m.

It is interesting to note how the difference in altitude between the snow line limits calculated for the two stages identified in the Bratica Valley and the corresponding ones in the Parma Valley in both cases differ by just over 100 metres (a difference of 119 m between the two snow line limits corresponding to the LGM in the two valleys and 102 m for those attributable to the I Late Glacial Stage). The reason for this is to found in the differences in morphometry and position of the accumulation areas of the two glaciers. In our opinion this also explains why glacialism soon disappeared in the upper Bratica Valley. The increase in the height of the snow line limit indicated by Federici & Tellini (1983) for the II Late Glacial Stage in the Parma Valley, compared to that of the maximum glacial advance is between 372 and 435 metres; if this fact is taken into consideration, it is obvious that for the Bratica Valley this limit must have, at best, been just below the maximum elevation of the valley head, therefore rendering the formation of proper glaciers impossible.

Some remarks about the glacial evolution of the Parma Apennines

An attempt to provide the absolute chronology of the glacial stages in the Bratica Valley was defeated by the fact that no datable material has been found and by the absence of current glacialism to refer to, as in the rest of the Apennines, except for the Calderone Glacier (Gran Sasso d'Italia). Therefore the chronology of events adopted by Federici & Tellini (1983) for the Parma Valley has been employed. The authors linked the maximum glacial advance stage (Parma Valley Phase, LGM) with the main Würm in the Alps (20,000-16,000 yr B.P.). This position is shared by Jaurand (1998), who referred the maximum glacial advance stage to 19,000 yr B.P. in his work on glacialism in the Apennines. Giraudi & Frezzotti (1997) dated this glacial stage in the massif of Gran Sasso d'Italia between 22,000 and 23,000 yr B.P., on the basis of a ^{14}C age (22,680±630 yr B.P.) obtained from organic material found in a lacustrine deposit in the Coppone Valley which was formed by the glacier tongue of Campo Imperatore barring the valley.

On the basis of the value of the raising of the snow line limit compared to the maximum glacial advance, Federici & Tellini (1983) attributed the I Late Glacial Stage to the Oldest Dryas.

Jaurand (1998) instead based the reconstruction of Late Glacial events in the Parma section of the Apennines on pollen diagrams and radiocarbon dates performed by Lowe (1992) on some cores found in two palustrine deposits in the Cedra Valley, closed by frontal moraine ridges. The author attributed the two moraine ridges to the II Late Glacial Stage in the Apennines, for which he maintains the division into two sub-stages (IIa e IIb) suggested by Federici & Tellini (1983). The 5.19 m long core extracted in the site named Prato Spilla C (1,350 m altitude, sub-stage IIa) has provided, at approx 50 cm from its base, the age 12,360±55 ^{14}C yr B.P. in correspondence to a palynologic signal which can definitely be attributed to the cooling of the Younger Dryas, well determined for Southern Europe. On the basis of this Lowe (1992) attributed the basal part of the core to the complex Late Glacial Interstage which preceded the Younger Dryas, here represented, in his opinion, starting from 13,000-14,000 yr B.P.. It must be pointed out that Lowe would rather not use the definitions Oldest Dryas, Alleröd and Bölling, as he believes that there is no evidence to apply this scheme to the sediment sequences of Northern Italy and that these definitions are not definitely applicable to every site in Southern Europe (Andrieu, 1991; Clerc, 1988; De Beaulieu & *alii*, 1984; De Beaulieu & Reille, 1978; Laval & *alii*, 1991; Penalba, 1989). As to sub-stage IIb the base of the sediment sequence extracted from the site named Prato Spilla A (1,550 m altitude) (Lowe, 1992) has provided the age 10.610±45 ^{14}C yr B.P. in correspondence to the palynologic signal attributable to the Younger Dryas. On the base of this Jaurand (1998) attributed sub-stage IIa to the Oldest Dryas and sub-stage IIb to the Younger Dryas, therefore setting the I Late Glacial Stage immediately after the maximum glacial advance and considering it a simple brief stop of the glacier tongues during their retreat from this position.

In this connexion, Lowe (1992) appears to be rather puzzled by the meaning of the radiocarbon age obtained from borehole Prato Spilla A. Comparing the value of the ELA calculated on the frontal moraine ridge of Prato Spilla A, equivalent to 1,650 m, with the ones found by Porter & Orombelli (1982; 1985) for the Western Alps and by Palmentola & *alii* (1990) for the Southern Apennines, equivalent to 2,100 m, he admits that this value appears to be extremely low. He tries to explain such anomaly by attributing:

a) to the radiocarbon age 10,610±45 ^{14}C yr B.P. the minimum age value for the deglaciation of the area, therefore referring the frontal moraine ridge which bars the lacustrine deposit to a glacial stage which preceded the Younger Dryas, considering that part of the sedimentation in the lacustrine hollow may have gone lost or that the Late Glacial sediments may be present but covered by an impenetrable layer of coarse material;
b) to the altitudes of the ELA calculated for the Western Alps and the Southern Apennines values which are too high, considering that none of the glacial landforms utilised to obtain these value has actually been dated;
c) the low altitude value of the snow line limit to local climate conditions during the Late Glacial.

DISCUSSION AND CONCLUSION

The present study has pointed out the presence in the Bratica Valley of landforms and deposits which allow to reconstruct its geomorphologic evolution presumably starting from the Middle Pleistocene at least.

Despite their state of preservation, the glacial landforms and deposits of the valley head have allowed to testify to two main glacial stages. The first is proved by Mt. Navert's deposit and was discussed by Federici (1979) and Federici & Tellini (1983); it can be attributed to a glacier whose accumulation area was on the main divide of the Apennines, at approx 3 km from the head of the Bratica Valley as the crow flies.

This study has allowed us to further specify the limits of the glacial deposits attributable to this ancient glacial stage by identifying new deposit's remains along the ridge between Mt. Navert and Mt. Verniceto. This fact has highlighted a greater distribution of glacial deposits than was previously hypothesised and confirmed the great extension of this glaciation, which developed in a very different morphological situation from the present one. In accordance with previous authors, due to the absence of absolute dating as reference, we feel we can confirm its attribution to a stage preceding the Parma Valley Phase (corresponding to LGM in the Alps), likely to the stage known in the Alps as Riss. We suggest that the equivalent stage in the Northern Apennines is named Mt. Navert Phase.

A second stage of glacial advance was afterwards identified, and the traces are visible along the head of the valley and on the sides of the ridge Mt. Navert-Mt. Quadro. Thanks to the preservation of the frontal and lateral moraine ridges the snow line limit (s.l.l.) has been calculated with the Höfer method (1992), in order to identify the maximum glacial advance stage (s.l.l. at 1,381 m a.s.l.) and the I Late Glacial Stage (s.l.l. at 1,477 m a.s.l.). This confirms that even in the Bratica Valley glacialism evolved from the Pleniglacial, when the glacier tongue was at its deepest in the valley, to the glaciers rapidly disappearing through stadial stages.

Not having found any material useful for radiocarbon dating, we have been forced to refer to geomorphologic evidence and the chronology of events suggested by Federici & Tellini (1983) for the Parma Valley even for the maximum glacial advance stage and its stades.

The snow line limits calculated for the stages in the Bratica Valley are consistent with the ones identified by these authors. We believe that the difference in altitude of approx 100 m for similar stages is to be attributed, on the one hand, to the smaller size of the accumulation area of the Bratica Valley glacier, and, on the other hand, to its marginal position compared to the main ridge, with a lower contribution of snowfalls. In our opinion the Bratica Valley bears proof of the Parma Valley Phase (Pellegrini & *alii*, 1998), which represents the maximum advance stage of the glaciers in the Parma section of the Apennines (LGM), and can be linked to the main Würm in the Alps and the I Late Glacial Stage (I Apennine stage), attributable to the Oldest Dryas according to Federici & Tellini (1983).

Morphological evidence confirm the action of periglacial processes on the sides not occupied by glaciers or freed during the retreat stages. Even in this case, on the basis of sedimentologic and compositional features, together with their position, it has been possible to suppose the existence of at least two generations of cryogenic and nival landforms.

The most recent ones, concentrated around Groppo Fosco, appear to have formed at the time of the cooling in the last glaciation, when the heavy climate conditions favoured the weathering of the slopes with phenomena of congelifraction, gelifluction and washing away tied to the prolonged presence of a thick snow cover on the ground.

The chronological attribution of the cryogenic deposit found S of the village of Lago di Corniglio appears to be even more difficult. Once again we can only make hypotheses on its age as there is no dating to refer to in the surrounding area. The only definite date is the one for the Carobbio landslide, which indicates a phase of activity during the Pleniglacial (25,129±160 ^{14}C yr B.P. and 17,330±110 ^{14}C yr B.P. corresponding to 21,200-20,060 ^{14}C cal yr B.P. (2σ), Stuiver & *alii*, 1998). As the Carobbio landslide affects a whole slope on the River Parma without being in a situation of inverted relief and has had a long permanence time, it may indirectly suggest a much older age for the «deposit of Lago». For this we suppose that it may have been active in a cold period preceding Parma Valley Phase, presumably during the Mt. Navert Phase.

The presence of inactive and/or dormant landslides whose position highlights a long evolution of the slopes, e.g. the landslide body which supports the village of Corniglio or the one affecting the villages of Ballone and La Costa, leads to believe that these processes became particularly active (or reactivated) at the same time as the glacial and periglacial processes.

Once again this is indirectly proved by the dating of the Carobbio landslide, although the phases of activity of many ancient landslides in the Parma and Reggio Emilia sections of the Apennines are Postglacial, being set in two time spans: most in the period 1,800-5,600 cal y B.P., and only some in the period 6,350-9,600 cal yr B.P. (Bertolini & Tellini, 2001).

The evolution of these landslides continued until the present day through reactivations which re-occurred at intervals of one or more centuries, as is proved by the history of the Corniglio landslide.

The morphogenesis due to gravity is to be found in the climate conditions which favoured physical and mechanical weathering of the rocks, and also in the Plio-Pleistocene uplifts of the Apennines (Bernini & *alii*, 1994). The latter favoured the increase in energy of the relief and the formation of tectonic discontinuities which, in some cases, helped to unblock vast sections of the slopes.

The processes currently acting in the Bratica Valley are mainly due to gravity or tied to the action of running waters; the action of the former is tightly linked to the action of the latter, as surface waters mainly act through linear and surface erosion. This is proved by the presence of scarps located at different heights along the River

Bratica and in the general tendency to deepening of the thalwegs. This situation leads to the undermining of the landslide bodies, affected by reactivations which are often of large dimensions, such as the landslide which broke off under the cemetery in Sivizzo in November 2000. The main trigger factor for the landslides is to be found in the amount of rainfall in the area. The intense rainfalls which occur mainly in the autumn contribute to plasticize the clayey component of both landslide bodies and outcropping rocks, and to the increased neutral pressures in debris covers.

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