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GEOMORPHOLOGICAL FEATURES AND CARTOGRAPHY OF THE GRAN SASSO D'ITALIA MASSIF BETWEEN CORNO GRANDE-CORNO PICCOLO AND PIZZO INTERMESOLI

ABSTRACT: PECCI M. & D'AQUILA P., *Geomorphological features and cartography of the Gran Sasso d'Italia massif between Corno Grande-Corno-Piccolo and Pizzo Intermesoli*. (IT ISSN 0391-9838, 2011).

The detailed geomorphological study and cartography presented here is part of a multidisciplinary study that includes snow profile monitoring and meteo-climatic, geomorphological and glaciological surveys in the area of the Gran Sasso d'Italia massif, all aimed primarily at the characterisation and mitigation of active geomorphological processes (D'Aquila, 2004; D'Aquila & Pecci, 2006; D'Aquila, 2007; Pecci & *alii*, 2007; Pecci, 2009; Pecci & D'Aquila, 2010). These processes usually develop rapidly, and they include snow avalanches and landslides (particularly rock fall and toppling). This work completes a study of the summit area of the Gran Sasso d'Italia massif that was already published for the Corno Grande-Corno Piccolo area (D'Alessandro & *alii*, 2003).

The study area is located close to the principal thrust of the Gran Sasso d'Italia massif, whose landforms are mainly controlled by geological, structural and glacial processes. In fact, important morphostructures have been identified as being linked to the direct action of tectonics at the macro-scale level, as in the case of the orientation of the principal valleys. Tectonics have also promoted the spread of gravitational phenomena.

The glacial footprint is evident in the numerous inactive erosive and accumulative landforms related to the LGM (Last Glacial Maximum) and in the presence of the Calderone Glacier («*Ghiacciaio del Calderone*» in the map), which, although divided into two aprons since 2000, is still considered the southernmost glacier in Europe. Landforms related to cryogenic processes are common, as are karst, fluvial, fluvio-glacial and slope landforms created by running water. Humans are only sporadically present but are capable of encountering risk situations when interacting with the gravitational dynamics linked to rock fall (as in the case of the «Paretone» landslide of August 22nd, 2006) or to snow avalanches.

The terrain data have been digitalised, processed and mapped in a GIS (Geographic Information System) environment at the 1:10,000 scale.

KEY WORDS: Geomorphological mapping, GIS, Gran Sasso d'Italia, Ghiacciaio del Calderone.

INTRODUCTION, GEO-ENVIRONMENTAL AND GEOMORPHOLOGICAL SETTING

The study area is located in central Italy, in the northern part of the Abruzzo Region in the «Gran Sasso d'Italia - Monti della Laga» National Park (fig. 1).

The study area is located primarily in the municipal territory of Pietracamela (TE), between the village to the north and the area of Campo Pericoli to the south, and it includes wide depressions located southward and below the western peak («Vetta Occidentale» in the map) of Corno Grande which, at 2,912 m a.s.l., is the highest peak of the Apennines. The area is delimited along the eastern side by the Cornacchie valley («Valle delle Cornacchie» in the map) and the edge of Arapietra and, on the western side, by the watershed bordering the top (2,635 m a.s.l.) of Pizzo Intermesoli. The area's climate (D'Alessandro & *alii*, 2003) is characterised by a bimodal precipitation distribution and by a clear warming trend in recent years (Pecci, 2007). It was estimated (Federici, 1979) that, during the LGM, the seasonal snow limit in the central Apennines has varied from 1,500 m a.s.l. for the western region (Mt. Morrone) to 1,900 m a.s.l. for the eastern region (Laga Mts.), whereas the freezing point was many metres lower, thus creating favourable conditions for glacial morphogenesis; also nowadays it is not uncommon to detect winter temperatures of –25 °C, which are unusual for these latitudes. Moreover,

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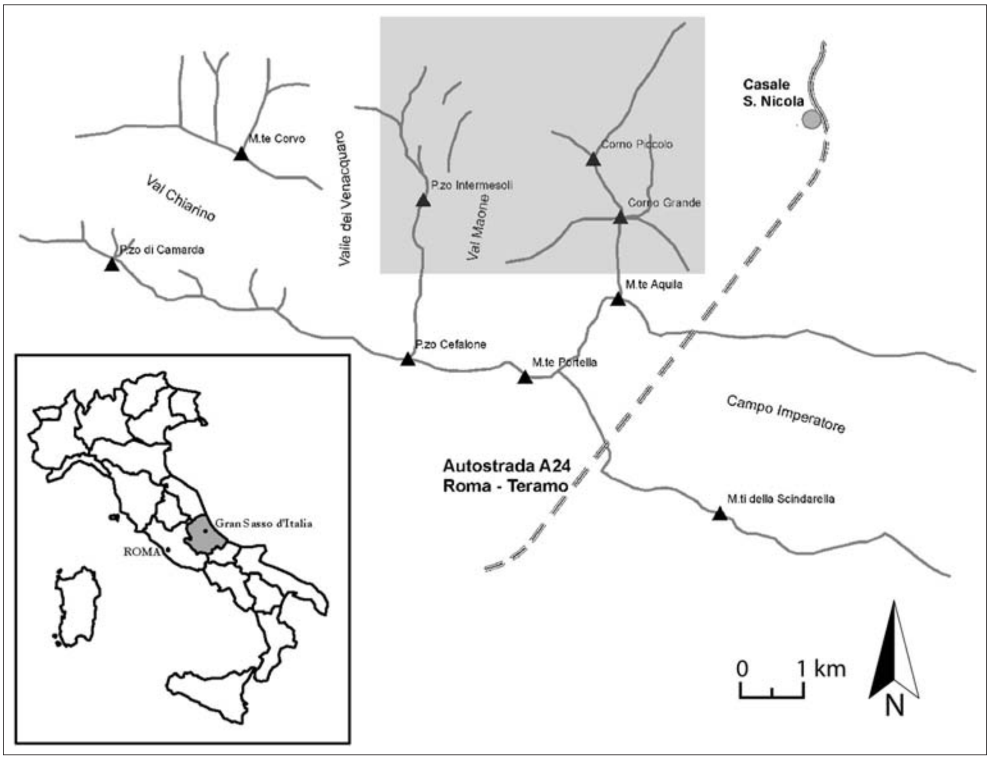


FIG. 1 - Topographic sketch of the central area of the Gran Sasso d'Italia massif displaying the distribution of peaks and the orientations of the main ridges**.** This sketch is used in all the following photographs to show the point of view of the photograph, as indicated by the view angle.

with stable high pressure cells, the phenomenon of thermal inversion develops in the basins and valleys, causing the stagnation of masses of cold air at low altitudes and creating at the same time climatic conditions in the glacial cirques that prolong the frost days and allow snow to persist for long periods. This phenomenon occurs in the Sambuco Trough («Conca del Sambuco» in the map), in the Cornacchie valley and on the Calderone Glacier, prolonging its survival. The abundant winter precipitation contributes to the presence of snow cover for long periods, ranging from around 30 days in the semi-mountainous areas, to about 60 days at an elevation of 1,000 m a.s.l., and to approximately 210 days at Campo Imperatore (outside the map).

From the geological point of view, it is important to highlight that the area is the result of the evolution of a chain-foredeep-foreland system, with the migration sector by sector of compression from west to east (Calamita & *alii*, 2002). The orogenic structure developed through the convergence between the European and African plates and the subsequent compressive deformation of the respective initial margins. This tectonic phase, which developed starting in the Miocene, was subsequently followed by an extensional phase also migrating from west to east (Bally & *alii*, 1985). The gradual uplift of the area during the Pleistocene (D'Agostino & *alii*, 2001; Bartolini & *alii*, 2003) created the conditions for intensive slope wasting accompanied by the deposition of thick sedimentary sequences, that filled the structural depressions created by the extensional tectonics. Considering that the growth of the chain occurred during the Pleistocene, in conjunction with important climatic fluctuations (Bisci & *alii*, 2000; Gori & *alii*, 2007), it can be understood how, from a temporal perspective, the Glacial Age left the most obvious morphogenetic footprint of large glaciers, that have created typical landforms such as cirques, U-shaped valleys, smoothed surfaces and glacial deposits. There are also landforms that can be related to tectonic-structural control, such as the north-south trending Calderone valley, Venacquaro valley («*Valle del Venacquaro*», outside the map), Maone valley («*Val Maone*» in the map), Cornacchie valley, Inferno valley («*Valle dell'Inferno*», outside the map) and the east-west trending Chiarino valley («*Valle del Chiarino*», outside the map) and the Campo Pericoli depression. Whereas these latter valleys have developed under the control of faults, the north-south trending ones were controlled by the monoclinalic setting of the Mt. Corvo-Pizzo Intermesoli range. Here the structural footprint makes the large frontal syncline evident, where erosional modelling and uplift have developed synchronously, reflecting rapid dynamic interactions between structural factors, erosive processes and sedimentation. Also, there is evidence of active tectonics in the south-western edge of the range, which has been active from the middle Pleistocene until now, as in the case of the Paganica fault (Blumetti & Guerrieri, 2007; Falcucci & *alii*, 2009) responsible for the L'Aquila earthquake of April 6th, 2009. The effects of tectonic activity are widely evident from the rock fall deposits present in the Calderone Glacier cirque and at the toe of the eastern wall of Corno Piccolo, both directly attributable to the 2009 earthquake.

The deposits, particularly those of glacial origin, were considerably important for determining and dating recent events in the area (Giraudi & Frezzotti, 1995; Carraro & Giardino, 1992; Jaurand, 1996; Juarand, 1999) based on morphological evidence or, more directly, on the locations of fragile deformation. In addition, glacial outcrops occur in the high valleys of the Ruzzo River (close to Pretara, outside the map) and the Leonora River (near Castelli, outside the map) between 600 and 800 m a.s.l., confirming the extent of the past glacial process. Another example of a glacial/cryogenic relict landform is the rock-glacier (described in Dramis & Kotarba, 1994) at the base of the southern slope of Mt. Aquila, a few hundred metres out of the map southern border.

The retreat of glacial tongues and their subsequent confinement inside the cirques have established the typical landforms of cryogenic processes in the areas vacated by ice, such as protalus ramparts, rock glaciers, nivation hollows, avalanche channels and deposits, and landforms and surfaces affected by cryosolifluction. Moreover, frost-wedging applied to the carbonate bedrock, which is structurally predisposed to physical degradation, has favoured the production of the scree slopes located at the toes of rocky walls and the talus cones at the outlets of rock channels.

In addition, gravitational processes affect rock slopes with roto-translational landslides and falls, which manifest their effects in different ways depending on the structural conditions, rock type, strata attitude and slope.

Morphological evidence indicating tensional release due to deep-seated gravitational slope deformations (DSGSD) were found at Mt. Portella (outside the map), on the edge of Arapietra, in the Piana dei Laghetti area (outside the map), on the summit of Corno Piccolo, on the eastern peak («*Vetta Orientale*» in the map) of Corno Grande («Paretone») and close to the northern slope of Pizzo Intermesoli.

Surface running waters have had a subordinate morphogenetic role in the mapped area.

GEOMORPHOLOGICAL SURVEY AND CARTOGRAPHY

Taking into account the guidelines of the Geomorphological Map of Italy 1:50,000 (Brancaccio & *alii*, 1994, updated in Cosci & *alii*, 2007), some adjustments were made to ensure optimal data management in the GIS environment and a representation that is understandable and usable for surveying and printing.

Terrain data were collected through a detailed survey of the area at the scale of 1:5,000 using Global Positioning System (GPS) technology and restituted to a scale of 1:10,000. The survey was followed by digitising, processing and mapping data in a GIS. The digital environment allowed the potential of the system to be exploited to analyse the morphometric parameters of the surveyed landforms in a geo-statistical way and to easily manage, update and interface with other software and methodologies (*i.e.*, remote sensing).

Photographic images, when included in the work, contain the location of the point of view and the field angle shoot.

Symbols were placed in a legend characterised by distinct colours, each assigned to a given process. In addition, for every type of landform, a further subdivision between landforms attributable to erosive or constructional processes was made. The landforms developed in surface areas were generally represented on a white background or a light bedrock colour in cases of limited and superficial thickness; if related to a characteristic element (such as a talus cone), the symbol was reproduced directly by drawing the shape.

The topographic base map consists of a mosaic from the union of four ortophotomaps at a 1:10,000 scale including sections: 349-070, 349-080, 349-110 and 349-120 (Regione Abruzzo, 1982a; 1982b; 1982c; 1982d) aero-surveyed in 1981 and published in 1982, from which it was possible to generate a Digital Terrain Model (DTM) useful for deriving the morphometric parameters and allowing more reliable geo-referencing of the mapped areas.

The geographic coordinate system refers to the UTM (Universal Transversal Mercator) ED (European Datum) 1950 fuse 33N.

Geological features inherent in the structural and tectonic data were derived from the geological cartography of Ghisetti & Vezzani (1990) and Vezzani & Ghisetti (1998) and subsequently reprocessed to be used in the geomorphological mapping. The bedrock formations, starting from the geological cartography, were grouped into the following geomorphological units, mainly according to their degree of strength with respect to the processes of degradation and erosion:

- Well cemented conglomerate and breccia;
- Alternating clay and sandstone;
- Marl and marly limestone;
- Bedded limestone;
- Massive limestone.

The units were mapped with pale colours to draw the various landforms produced by geomorphological processes over them; where these processes are represented on a white background, they are of consistent thickness.

Superficial deposits were distinguished according to genetic process regardless of its degree of cementing or age.

Concerning the cartographic representation of strongly fractured surfaces, it should be noted that the symbol refers to the special structural conditions where outcrops are strongly affected by joint systems, such as at the Due Corni saddle («*Sella dei Due Corni*» in the map) and along the ridge that leads to Corno Grande, where a thin bedded marly outcrop ("Verde Ammonitico" Formation) is affected by folds. All of these conditions promote the production of abundant frost-wedged debris.

With regard to the evolutionary status, two classes of activity were distinguished because of the difficulty of precisely classifying morpho-evolution data, as previously discussed:

- landforms evolving due to active or dormant (reactivatable) processes;
- landforms no longer evolving and no longer reactivatable in the present morphoclimatic conditions and under the influence of the same morphogenetic process.

This distinction was made in the cartographic representation by using different shades of colour for the same morphogenetic process depending on its activity; darker shades were used for active processes, and lighter shades were used for inactive processes.

Morphometric data are directly derivable via digital processing in the GIS environment, especially the aspect and slope of the landforms (automatically retrievable from the DTM). Finally in the database, both the *sensu strictu* morphometric data (such as length/area, perimeter and relief) and the statistical data concerning these parameters (e.g., average exposure and slope) are collected.

RESULTS

The geomorphological map presents the results of the geomorphological survey. The main active processes in the area and their related landforms are described below in detail, using the geomorphological map of D'Alessandro & *alii*, 2003 as a reference. In the areas of cartographic overlap, differences in interpretation will be duly discussed taking into account the flexibility required in the drawings and in the locations of signs and symbols, which are due not only to the ongoing natural evolution but also to the use of different methods and technologies.

STRUCTURAL LANDFORMS

The main structural elements in the study area consist of thrusts, faults and joints systems. A brief description of these elements and the evidence for them follows.

The thrust of the Corno Grande (fig. 2) is the most important structural element of the area (Adamoli, 1992). It

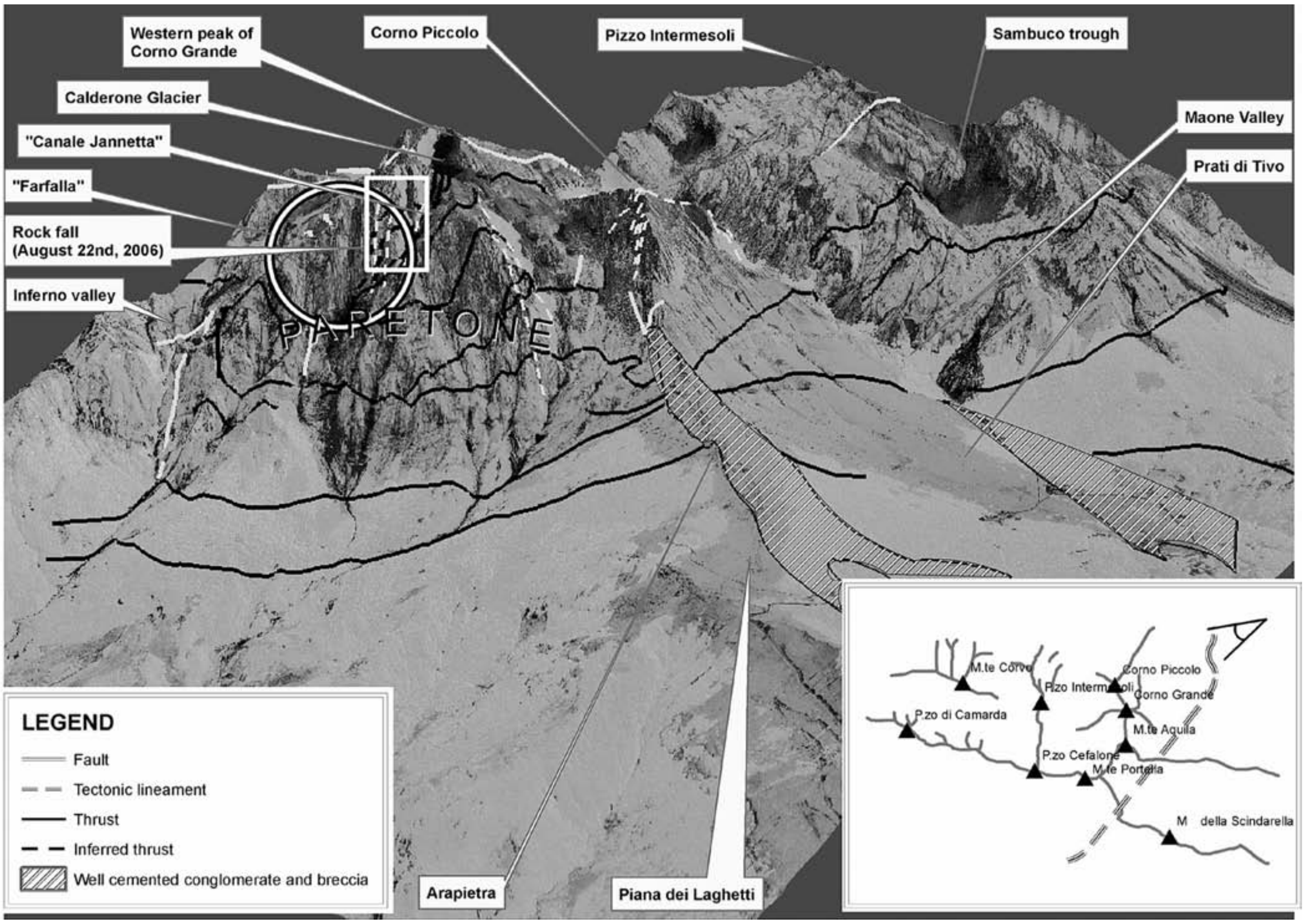


FIG. 2 - General 3D-view from ENE of the study area with major toponyms and tectonic lineaments. Notice how the «Paretone» is intersected by the confluence of several thrusts that determine its verticality; at the same time, the many features create a zone with greater erodability that crosses the whole «Paretone» in correspondence with Canale Jannetta. Similar concentrations of lineaments are visible close to the summit of Corno Piccolo and are responsible for numerous rock falls deposits into the Cornacchie valley and characteristic rock towers known as «Fiamme di Pietra» (fig. 3). Highlighted in the white circle is the surface of a large rock fall that occurred in 1897 known as «Farfalla» (butterfly), and in the white rectangle is the latest rock fall of August 22nd, 2006, analysed in detail in Pecci & Scarascia Mugnozza, 2007.

is visible at the base of the wall that plunges between the Brecciaio saddle («*Sella del Brecciaio*» in the map) and the Due Corni saddle with the NE-SW direction. In particular, the Corno Grande thrust cuts across the «Paretone» wall, revealing a highly erodable band that leds to the development of a large channel that separates the eastern peak of Corno Grande from the subpeak (2,755 m a.s.l.), known in the CAI Touring mountaineering literature (Abbate & Grazzini, 1992) as «Canale Jannetta» (fig. 2).

Another thrust determined the structural footprint of the area and influenced the main front of the whole chain, overlapping with the same direction the «Flysch della Laga» formation. A third thrust is visible in the Prati di Tivo area, at the entrance to the Maone valley and on the northern side of Corno Piccolo. This structural element is in an intermediate position relative to the previous thrusts. It is partly masked by Pleistocene breccias near the «La Madonnina», becoming clearly visible along the St. Nicola Creek («*Fosso S. Nicola*» in the map) after crossing the Scalette pass («*Passo delle Scalette*» in the map).

The southern slopes of the study area are characterised by the presence of the «Tre Selle» normal fault system (Ghisetti & Vezzani, 1990; Vezzani & Ghisetti, 1998), which shows directions similar to the previous structural features. This system is surveyable at Campo Pericoli, along the southern side of Primo Scrimone, on the western peak of Corno Grande, at the Corno Grande saddle («*Sella di Corno Grande*» in the map) and along the northern side of Mt. Aquila, from where it continues along the entire southern side of the eastern sector of the chain. At the Maone valley entrance, it was detected as the edge of a fault scarp with signs of Quaternary reactivation. This fault was described in the literature (Giraudi & Frezzotti, 1995), and it displaces Tardiglacial moraines between 1,860-2,000 m a.s.l. over approximately 400 m, with throws up to 3-4 m.

Other sets of normal faults trending NW-SE and NE-SW are distributed into three sectors at different elevations in the area of Campo Imperatore.

Joint systems characterise the SW wall, on the three «shoulders» («*Le Tre Spalle*» in the map) of Corno Piccolo, on the top of Coste del Calderone. A dense network of E-W vertical joints set characterises the walls of Corno Piccolo giving rise to typical rock towers (fig. 3) and causing the most significant rock falls of the mapped area, scree slopes and talus cones.

The north face of Corno Piccolo is rather sparsely affected by scree slopes and talus cones because of the orientation of the fractures themselves, which have a sub-direction that is parallel to the slope. During the survey, only the areas with a greater density of fractures that affect all walls were mapped.

In addition, conjugated fracture systems of «type R» (Riedel fractures) have been highlighted (D'Alessandro & *alii*, 2003), and they were detected on a rocky buttress in the Cornacchie valley at an elevation of approximately 2,100 m a.s.l. near the Scalette pass with orientations compatible with the stress field predicted for the Corno Grande-Corno Piccolo thrust. Other systems of conjugated fractures are visible on the rocky slopes of Corno Piccolo at an elevation of 1,600 m a.s.l. near the Arno Stream («*Rio Arno*» in the map) springs.

Various structural surfaces are visible on the slopes affected by rocky units with a slope-oriented attitude:

- below the edge of Corno Grande at an elevation of 2,650 m a.s.l.;
- under western peak of Corno Grande at an elevation of approximately 2,450 m a.s.l. on a bedded limestone («Calcare Massiccio» Formation) outcrop;
- in the Ginepri valley on green marl outcrops of the «Verde Ammonitico» Formation;
- under the Due Corni saddle;
- along the western side of Corno Piccolo between the elevations of 2,050 and 2,200 m a.s.l. on limestones and marls («Scaglia» formation) where the mountaineering trek «Via Ferrata Pierpaolo Ventricini» starts.

SLOPE LANDFORMS DUE TO GRAVITY

Rock falls are present throughout the area; when located inside cirques they are likely promoted by post-glacial release stress. The rock fall heaps consist of blocks heterogeneous in size and varying from a few centimetres up to

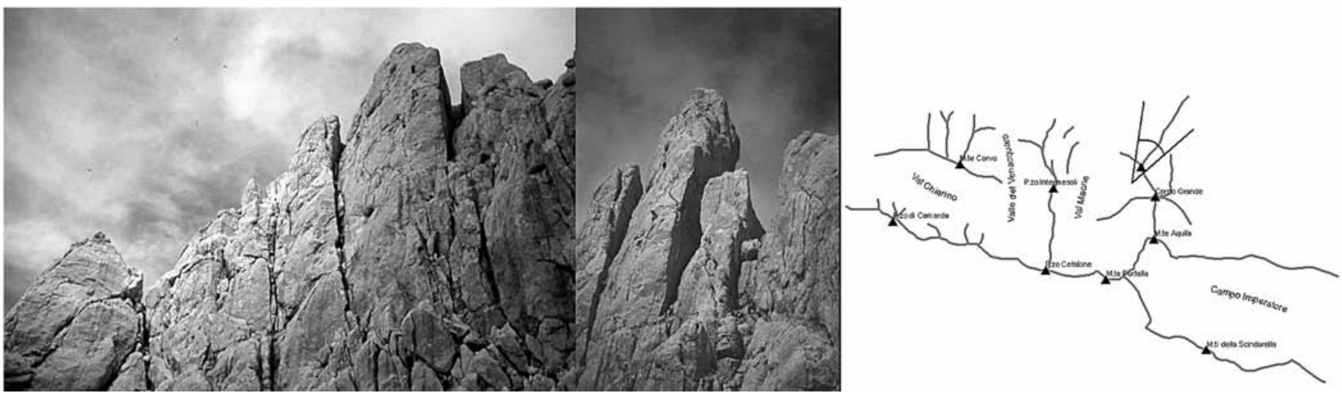


FIG. 3 - Detail of the joint system highlighting the «Fiamme di Pietra» rock towers (Corno Piccolo, southern ridge).

several metres. A small deposit was also detected on the Calderone Glacier central-lower part. This event is to be taken into account because large blocks are present at the slope toe with dimensions larger than one metre, and the mountaineering path originally passed on the walls above. This phenomenon is attributable to tensional release secondarily linked to glacier shrinking after the Little Ice Age. In the same sector, two small new debris deposits from rock falls appeared in the summer of 2009 on both sides of the lower walls of the cirque that were linked to the earthquake of April 6th, 2009. A similar (but more important) phenomenon in the same period affected the rocky channel just below the top of Corno Piccolo, known in the mountaineering literature as «Immondezzaio». A large rock fall detached from the base of the 4th pillar of the «Paretone» on August 22nd, 2006; an influence of permafrost or seasonal ice degradation is not to be completely excluded considering its elevation and exposure (Pecci & Scarascia Mugnozza, 2007). These phenomena are particularly interesting because the high-altitude environment, no longer in morphoclimatic equilibrium (D'Aquila, 2007), is very sensitive to climatic fluctuations and, consequently, can be considered as an environmental indicator for large geographic areas, as in the case of the many gravitational collapses that have occurred recently in the Alps due to permafrost degradation (Dramis & *alii*, 2002; IMONT & AIGEO, 2006). Among the rock falls of large dimensions, the first place pertains to the «historical» rock fall of the «Paretone» that occurred in 1897 (Pecci & Smiraglia, 2001; Pecci & Scarascia Mugnozza, 2007). The surface detachment is still clearly visible (fig. 2) and is marked by a significant butterfly-shaped chromatic contrast on a particular wall («Farfalla» is the toponym used by mountaineers). The edge of the rock fall scarp is located at an average of 2,450 m a.s.l., with a front approximately 200 m long and a slope overhanging from the vertical by more than 10 m. Preliminary results of recent studies, carried out after the August 22nd, 2006 landslide event (Pecci & Scarascia Mugnozza, 2007), suggest that the «Farfalla» landslide occurred also in 1897 (as referred in the mountaineering literature) and likely in 1827 (Cappello, 1828). Coalescing rock falls of large dimensions produced the block deposits of the Cornacchie valley. Upstream, a single edge is not detectable because of rock fall events that occurred and are still occurring to a certain extent along the entire eastern wall of Corno Piccolo with different smaller block falls derived from jointing (fig. 3). Also, there are current and forthcoming landforms with blocks partially detached and rotated from the vertical wall clearly visible near the Cornacchie Cave («*Grotta delle Cornacchie*» in the map). Approximately under the second «Shoulder» of Corno Piccolo, there are other rock fall scars with edges that are not always well defined but instead are constantly evolving, as in the case of the rock fall that took place in autumn 2007 modifying the summit morphology of «Campanile Livia». Another large rock fall scar is located under the rocky ridge of the northern flank of the Arapietra crest. This landslide affects strongly cemented Pleistocene breccias, covering the underlying units of «Flysch della Laga» and creating an unconformity. Rock falls scars with active and well-visible edges are present on the south-eastern slope of the Arapietra crest, but with a body not always easily identifiable due to strong slope dipping.

Rock falls affecting outcrops of competent rocks (cemented Pleistocene breccias) and signs of lateral enlargement of the crest such as cracks on either side of the crest itself may be related to the state of tensional release now characterising the whole top of the Arapietra (D'Alessandro & *alii*, 2003). Other signs of likely DSGSD explicitly linked to the structural setting are located behind the eastern peak («*Vetta Orientale*») of Corno Grande (fig. 4) and the top of Corno Piccolo (fig. 5).

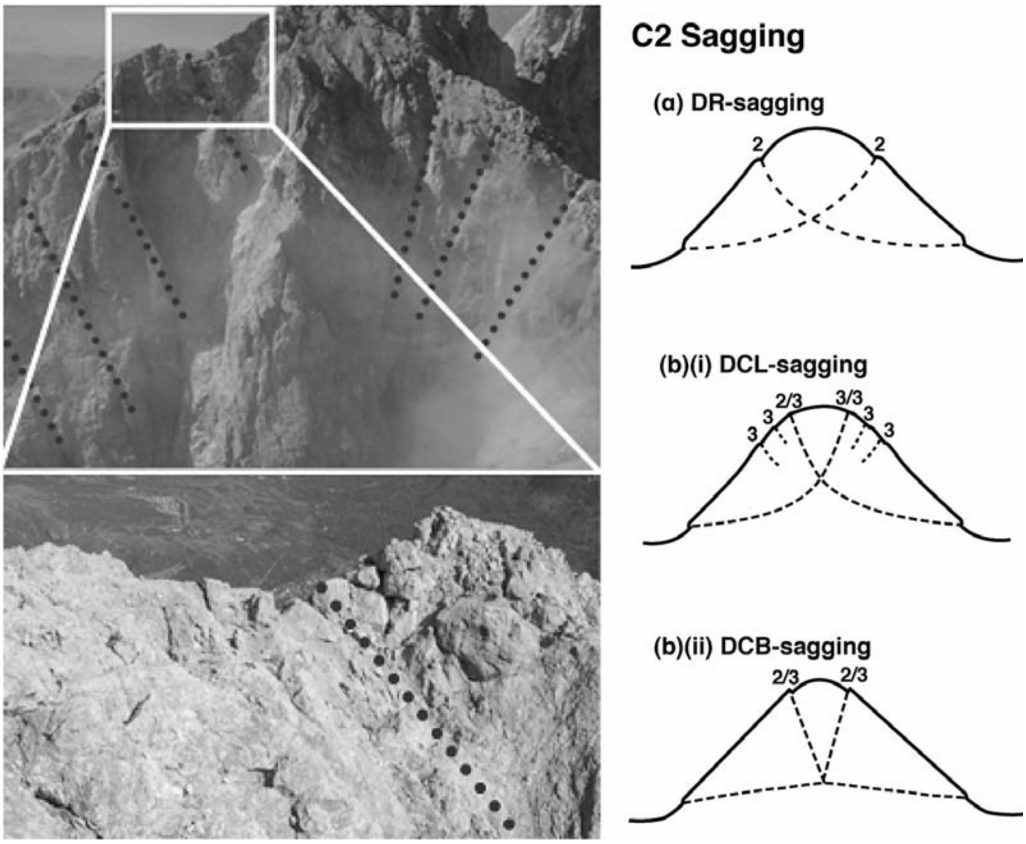
The former presents typical geomorphological evidence of a *sackung Auct.* (DSGSD «C2» type *sensu* Hutchinson, 1988); the latter is characterised by a wide tension crack affecting the sector from the top down towards the Ginepri valley, which can be interpreted as superficial evidence of a recent deformation process active in the more deformable formations buried at the toe of the main thrust of the massif (fig. 2).

At Piana dei Laghetti (outside the map) a trench is visible, which is probably attributable to post-glacial tensional release and is also favoured by prominent local relief. Other signs of DSGSD, suggesting once again post-glacial tensional release, are present on the eastern side the long ridge connecting the northern slope of Pizzo Intermesoli with Pietracamela, as illustrated by recent studies that support an extension of glacial tongues much larger than those documented to date (Demangeot, 1965; Gentileschi, 1967; Federici, 1979; Ghisetti & *alii*, 1990; Aringoli & *alii*, 1997; Jaurand, 1999).

A showy rock fall deposit is located almost in the centre of the Maone valley at an elevation of approximately 1,600 m a.s.l. It is colonised by herbaceous vegetation and even by trees and is composed of large boulders, with sparse fine material. The rock units concerned and the location suggest they detached from an edge, no longer clearly visible, located in the mid-face of the slope on the true left side of the Ginepri valley, where massive stratified carbonatic rocks outcrop («Calcare massiccio» and «Corniola» formations). As in the case of the other large rock falls previously discussed (Pecci & Scarascia Mugnozza, 2007) for this phenomenon, an implication of permafost degradation (Dramis & *alii*, 1995) in the recent past is plausible.

Along a front of approximately 800 m, a large dormant landslide affects the eastern side of the northern slope of Corno Piccolo in the thrust zone (the lower in fig. 2) of the Gran Sasso d'Italia unit on the «Flysch della Laga» unit (Adamoli, 1992). A rotational surface is clearly visible on the upper sector with a length of more than 500 m; then the sliding body is intersected by antiscarps in the central sector and by chaotic flows in the lower sector. The landslide deposit, which is completely colonised by herbaceous vegetation, stretches a short distance from the car park and is intersected by obvious antiscarps. Clayey rocks with upturned strata inclined to 65° are involved; close to the scarp edge, where there is major inclination, debris (peb-

FIG. 4 - Summit area of the «Paretone»; the morphological features are typical of a sackung *Auct*. or type «C2» DSGSD of the Hutchinson (1988) Classification. The photo below shows the view from the opposite side of the trench and its double ridges as outlined in the white box.



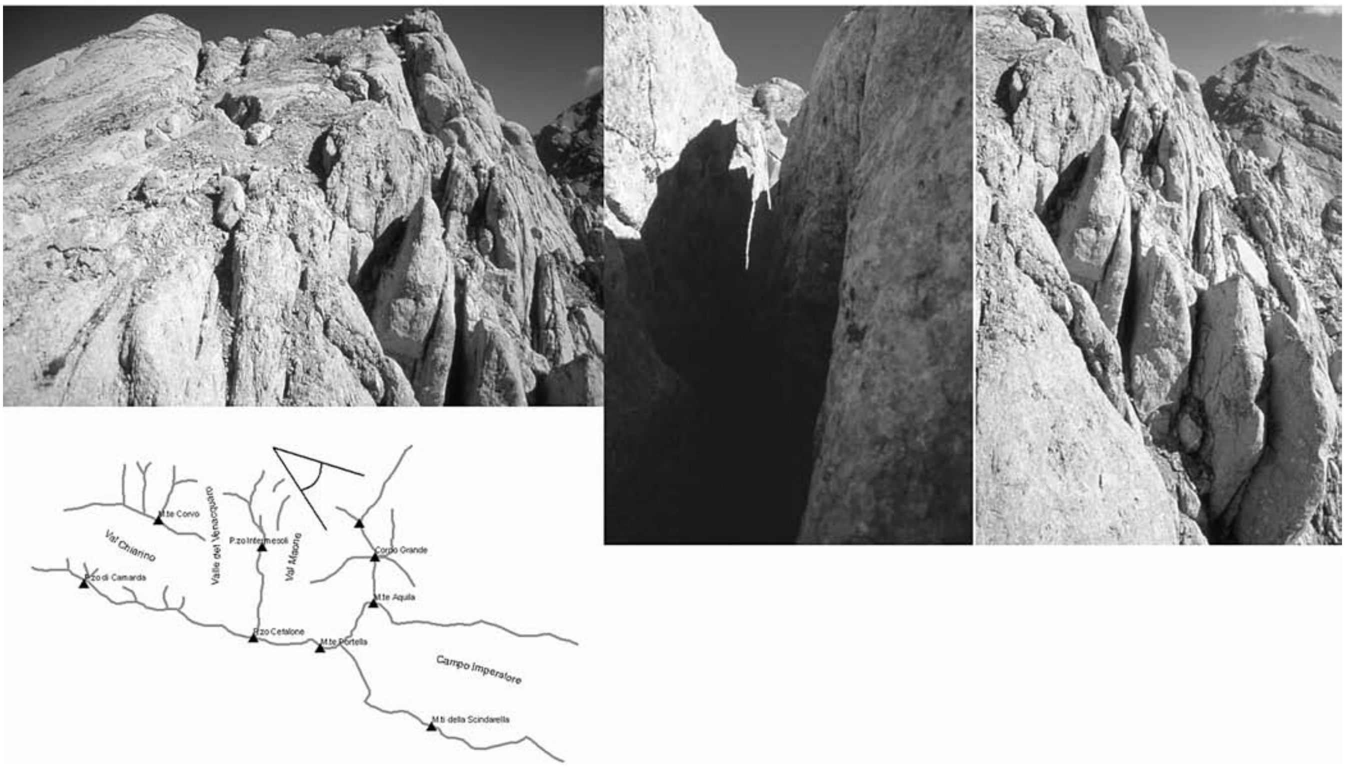


FIG. 5 - Tensional release on the summit of Corno Piccolo (2,665 m a.s.l.), promoting the rotation of isolated blocks and subsequent collapses, topples and falls.

ble sized) falls down even today, producing small scree slopes inside the edge itself upstream of the antiscarps.

A large-scale landslide body, partially reactivated during the earthquake of April 6th, 2009, has been mapped in the vicinity of Pietracamela. It was classified as a complex landslide (Centamore & *alii*, 1997; Regione Abruzzo, 2005; CNR-GNDCI, 1995-2011).

Debris flows are present under the Scalette pass and on small scree slopes under the Calderone Glacier on the true left, where the debris fields, likely reworked by rainwater and melting water, are not visible due to the high slope. The debris flow found on the northern slopes of Pizzo Intermesoli is relevant for its size and activity; it is a form that has likely been active only in very recent years.

The south-eastern slope of the Arapietra ridge is affected by solifluction phenomena in the area below the outcrops of Pleistocene breccias. These phenomena are most evident near the «Madonnina», where irregular lobes and depressions occur in the arenaceous-clayey rocks in layers inclined by 60° to the slope. In the zones colonised by timber (outside the map and adjacent to Prati di Tivo), the trees exert a stabilising action through their radical *apparata*, and the slope is affected by solifluction phenomena of minor intensity. Here the process can be regarded as quiescent and presents small areas of activation; in this area, at an elevation of 1,400 m a.s.l., sectors devoid of trees were identified with evidence of solifluction.

Degradation scarp edges and ridges are present in areas where the rock is intensely jointed because of structural conditions, such as at Picco dei Caprai and Corno Piccolo.

Scree slopes are certainly the depositional landforms most characteristic of the area. They generally consist of sediments of sizes varying from pebbles to blocks that were frost wedged, detached and then accumulated at the foot of the slope. The inclination of the scree slopes varies between 20° and 25° in lower areas, and here they are characterised by the largest and most stable debris. Their inclination is between 30° and 35° in the higher areas, where they are characterised by an increased proportion of small, more angular sediments and by a mechanical condition close to the stability limit because the value of the natural slope angle is close to the internal friction value. Avalanches also contribute indirectly to scree slope construction. These deposits form tongues of debris that stand out (even chromatically) because they are composed of debris in a state of more obvious «freshness» than the existing older and weathered debris. In general, all the high altitude scree slopes are active. The inactive or dormant slopes located below elevations of approximately 1,800 m a.s.l. have been colonised by vegetation (trees and grass). In the case of both trees and herbaceous cover, narrow stripes of fresh debris indicate active deposition.

Talus cones are present at the outlets of rocky channels, especially in the Maone valley and on the northern slopes of Pizzo Intermesoli. The talus cone descending from the eastern slope of Pizzo Intermesoli is of considerable size. Here the alimentation, as well as the action of erosion, is favoured by this particular structure, which could be related to its reversed anticline geometry.

Eluvial/colluvial deposits are widely distributed in the lowlands of the northern sector of the study area, in particular in the areas covered by grass and/or forest and in the bottoms of the largest dolines.

FLUVIAL, FLUVIO-GLACIAL AND SLOPE LANDFORMS DUE TO RUNNING WATER

Deposits associated with surface running water are scarce. They are present mainly in the northern sector of Prati di Tivo, where a significant decrease in slope facilitates the deposition of alluvial material deriving from a nearby alluvial fan and from a large roto-traslational landslide body. The fan cited above, the only one present in the area, is located at the end of a long channel that concentrates water runoff from snow melting on almost the entire eastern sector of the north face of Corno Piccolo. It is largely inactive apart form minor activity traces detected along its eastern side.

Fluvio-glacial deposits, colonised by vegetation, are present in the Maone valley between the elevations of 1,590 and 1,650 m a.s.l. These deposits, partially covered by talus cones, consist of sub-rounded gravels and well classed pebbles with a poor matrix. In some places, the deposits are crossed by braided channels with no mappable dimensions. Similar but more abundant sediments were found close to the Rio Arno spring and along the Arno Stream valley between the elevations of 1,200 and 1,150 m a.s.l., where the valley is slightly wider.

The hydrographic network in the area is virtually absent; the Arno Stream is the only perennial stream and is fed by homonymous sources in the northern sector of the Maone valley. In some places, end-distributed gullies were observed in a sub-parallel pattern with respect to the maximum slope; in fact, the slope favours run-off and permits activity that elsewhere is virtually absent due to high water infiltration. In the centre of the Maone valley, an inactive gully developed as a collector of the water draining from Campo Pericoli. In this latter area, gullies are generally covered with grass and do not form a continuous network from the highest edges to the Maone valley entrance but instead stop in correspondence with a reversed slope of tectonic origin and modelled by both glacial and karst processes (D'Alessandro & *alii*, 2003). The Maone valley entrance stands several metres higher due to the tectonic lowering of the Campo Pericoli block that originated a structural depression that was refilled during a later stage.

Some landforms linked to the action of concentrated snowmelt water runoff are particularly interesting. These landforms are comparable to the sorted stripes of a cryogenic environment but differ from them with respect to their genesis, as discussed by D'Alessandro & *alii* (2003).

Finally, the surface of the «Paretone» is influenced (for the most part) by runoff water that converges towards the base into the few gullies surveyed (fig. 2).

KARST LANDFORMS

In this area, visible karst landforms are very limited because they are masked by other prevalent processes. Typical karst landforms are very small, generally funnel-shaped dolines with the diameters of most being between 1.5 and 2 m and a maximum diameter of less than 5 m. These occur mostly in the Brecciaio saddle area.

Underground karst landforms are scarce. Only two caves were detected: the Oro Cave («*Grotta dell'Oro*» in the map) has an opening of approximately 6 m in diameter and extends by ca. 25 m, and the Cornacchie Cave, smaller than the previous one. Both cavities develop horizontally into massive limestones belonging to the «Calcari a Entrochi» formation.

Karst micro-landforms (such as *karren*) are widely present on the walls of Corno Piccolo and where competent rocks are exposed to the corrosive action of water runoff, as in the case of large rock fall blocks and erratics. These micro-landforms are present on a rocky surface consisting of massive limestone («Calcari a Entrochi») elaborated by the action of water runoff and melting snow, which is more corrosive than rain because of the greater amount of dissolved CO_2. At the same time, alveolar surfaces are spread throughout the areas with micro-*karren*; this features are probably linked to the corrosive action of microorganisms (lichens), which paves the way for the establishment of dissolution phenomena as corrosive micro-niches that can evolve into micro-*karren* (D'Alessandro & *alii*, 2003).

GLACIAL LANDFORMS

The most outstanding feature of the glacial morphodynamics that is still active, even though it is in a state of crisis, is the Calderone Glacier, the description and recent evolution of which can be found in the literature, mainly by Pecci & *alii*, 1999; Pecci & *alii*, 2004; D'Alessandro & *alii*, 2003; Rovelli, 2006; Pecci, 2007; Pecci & *alii*, 2008; D'Aquila & *alii*, 2009.

Glacial cirques and valleys with transverse U-shaped profiles represent the most characteristic landforms of the area, reflecting the extension of glacial process from the summit of the Apennines. The glacial cirques show typical morphology almost everywhere with steep walls partly covered by scree slopes and an overdeepened bottom that is often bordered by a rocky reversed-slope threshold, as observed in the case of the inactive Sambuco Trough and of the active Calderone Glacier. Sometimes, however, the cirques show a degrading bottom in continuity with the slope below. The bottom generally hosts accumulations of rock fall induced by post-glacial tensional release. The edges of the cirques are generally re-modelled by degradation processes, as confirmed by the presence of scree slopes at the bases of the walls. These processes, however, have generally not altered the glacial landforms. Other smaller cirques are located:

- in the Ginepri valley;
- under the Three Shoulders of Corno Piccolo at an average elevation of 2,100 m a.s.l.;
- in both the slopes of the edge descending from the western peak of Corno Grande to the Brecciaio saddle at an average elevation of 2,150 m a.s.l. (the steps in the valley at an elevation of 2,040 m a.s.l. of structural origin do not preserve the glacial footprint as well as in other areas);
- in the Cornacchie valley near the «C. Franchetti» hut and just downstream of the Due Corni saddle between the elevations of 2,544 m and 2,400 m a.s.l.

The eastern slope of Corno Grande is characterised by walls with steep slopes and does not present cirques. By contrast, Corno Piccolo is characterised by an amphitheatre with a clear glacial footprint close to the summit.

The minor glacial ridges are not particularly sharp, due both to the geo-structural conditions and the less-developed glacial processes compared to the Alpine environment. The erosion of cirques does not always reach the summits of the ridges, where gravitational action is superimposed on cryogenic and running water processes. The ridges, apart from those located above the elevations of 2,500-2,600 m, are tens of metres wide, are colonised by low vegetation and have rounded tops.

Without doubt, the Maone valley-Arno Stream area displays the most well-preserved, typical glacial morphology. The glacial apparatus in this valley, together with the glaciers descending from the Mt. Aquila crest towards Campo Imperatore (outside the map) and from Pizzo Cefalone (outside the map), through Valle Venacquaro, were probably the largest and longest tongues of the Apennine range during the LGM. In fact, in the Maone valley, numerous glacial tongues were confluent, coming from a wide compound basin, as detectable in the geomorphological map. This basin extended (clockwise, from east to west) from the confluence saddle surveyed at the Due Corni saddle and behind the western peak of Corno Grande, passing through the crest of Duca degli Abruzzi hut and Mt. Portella, up to the ridge (fig. 1) of Pizzo Intermesoli. Moreover, on the basis of geomorphological evidence, consisting of layered glacial deposits, it is possible to assume the presence of a glacial transfluence saddle towards the glacier descending through the Venacquaro valley (outside the map) in the Colle dell'Asino area (1,440 m a.s.l.). If this assumption is verified with quantitative chronological results, the glacial processes in the central Apennines will have been substantially underestimated. The valley source (1,863 m a.s.l.) is located in the bottom of Campo Pericoli and is barred by a reverse slope caused by a fault during the Quaternary. The presence of extended scree slopes and talus cones along the valley did not mask the original glacial footprint of the landform. The continuity of the slopes is interrupted by rock channels and crags and by the confluence with the Ginepri valley, carved in marly rocks. In the lower part of the main valley, the U-shaped profile is made irregular by deep gorges separated by wide pronounced crests, which are localised in conjunction with thrusts. Moreover, the upper part of the St. Nicola Creek presents a U-shaped cross-section and a stepped longitudinal profile, which are both visible from the Scalette pass thanks to the persistence of the landforms, clearly highlighting the glacial abrasion process. Here, the presence of the steps is due to different degrees of strength of the rock, which is composed of massive limestones and is affected by secondary thrusts transverse to the valley. The steps do not present a reversed slope; in fact, they are inclined towards the valley, in agreement with the general structural attitude of the thick limestone layers. The same large rocky edge bisecting the lower part of the Cornacchie valley must have been affected by erosion from the «paleo-tongue» of the Calderone Glacier, which probably followed two flow lines before precipitating with an ice *serac* into the lower St. Nicola Creek. This large crest originated from a NE trending normal fault, which uplifts the northern sector of the area.

Roches moutonnèes outcrop only inside the cirques of the Calderone Glacier. They are particularly fresh and still active in the central sector of the cirque, which was recently exhumed due to the fragmentation of the glacier into two ice aprons (Pecci, 2006). They are also generally deeply weathered by karst process.

Glacial deposits are found abundantly in the Maone valley, where the principal Pleistocene glacial tongue descended. These deposits are composed of heterogeneous debris, sometimes with abundant matrix, or by simple stone stripes heavily altered by corrosion. They present states of vegetal colonisation that vary depending on age, elevation, percentage of clayey fraction (which determines the extent of soil development) and microclimate (humidity, temperature, light intensity, exposure and wind). All the surveyed glacial deposits, except those of the Calderone Glacier and those present in the Campo Pericoli area, are considered to be chronologically earlier than the Appennine II Stage (Giraudi & Frezzotti, 1995), which corresponds to the Alpine Buhl-Schlern Stage (Federici, 1979). The glacial deposits of the Cornacchie valley also vary in their degree of colonisation by vegetation. Located at an elevation between 2,400 m and 2,320-2,380 m a.s.l., they have appreciable thickness, whereas at the base of the scree slope descending from the frontal moraine of the Calderone Glacier, a thin layer of glacial origin reflects rapid retreat.

The moraine ridge located near the «C. Franchetti» hut at an elevation of approximately 2,400 m a.s.l. maintains a distinct shape with a frontal embankment several metres high. This moraine is covered by gravitational deposits occupying almost the entire Cornacchie valley and by an active protalus rampart on its inner side. The frontal-lateral moraine of the Calderone Glacier is more significant because it marks in a very incisive way the summit landscape of the Gran Sasso d'Italia massif. The frontal section is active, even if with a strongly shrinking ice core and with increasingly critical relations with the main and more depressed glacier sector. The lateral section is currently inactive because the continuity relationships with the glacial apparatus are no longer confirmed, at least according to the morphological evidence. This section presents obvious signs of shrinking and incipient ice core collapse, with superficial zoning and rapid displacement of glacial detritus (Dramis & *alii*, 2002; Pecci, 2006). In this area, a significant *serac* seems to have been active until the end of the XIX Century on the basis of the oldest available pictures (by Gilli in 1871 and Ugolini in 1887, both present in the iconoraphic archive of Italian Alpine Club of Rome) and on morphochronological reconstructions (Pecci, 2001), including those based on ^{14}C dating (Giraudi, 2002).

Other glacial deposits are located downstream of the Sambuco Trough cirques, which is now occupied by a snowfield that was perennial until a few years ago.

A glacial tongue descended from this area during the Pleistocene up to the Tardiglacial, bisecting the rocky ridge of Picco dei Caprai at an elevation of 2,000 m a.s.l.; it contributed to the primary tongue descending along the Maone valley and partly continued northwards, feeding the glacial tongue of the Venacquaro valley close to the transfluence saddle located near Colle dell'Asino, at an elevation of 1,440 m a.s.l.

Numerous recessive moraine ridges can be observed, both on the field and from aerial photos, as testimony to the retreat phases during the synchronous glacial fluctuations.

CRYOGENIC/NIVATION LANDFORMS

The cryogenic/nivation constructional landforms characterising high mountain slopes primarily consist of avalanche cones, turf-banked and debris lobes and protalus ramparts, with active rock glaciers and active rock streams occurring less abundantly.

The erosion landforms are represented by avalanche tracks, edges of nivation hollows and areas affected by the passage of seasonal avalanches.

Two types of lobes surfaces are present in the mapped area. The first (fig. 6), detected only behind the Due Corni saddle has been classified as active due to the presence of poor pioneer vegetation and the sub-horizontal arrangement of the underlying debris. These turf-banked lobes are usually located at a minimum elevation of 1,600 m a.s.l. in northern sectors, whereas on southern slopes, they are located at higher elevations.

The second type, surface with debris lobes, is characterised by the prevalence of granular material, by a lack of vegetation, due both to the greater inclination of the slope and the greater soil cooling during winter (linked to the intermittent presence of snow) and to the continuous displacement of individual grains in the summer season.

In less fresh areas of scree slopes and talus cones in particular, the grain arrangement is often organized in horizontal stripes. These landforms are not present in scree slopes and talus cones with slope angles greater than the friction angle of the debris component or in areas under strong human presence and movement.

The mapped areas are located predominantly in zones, such as the Maone valley and the Sambuco Trough where the presence of seasonal ice is not completely excluded; these areas are well enclosed by high walls, so that during the winter, they receive the sun radiation only a few hours each day due to its lower height on the horizon.

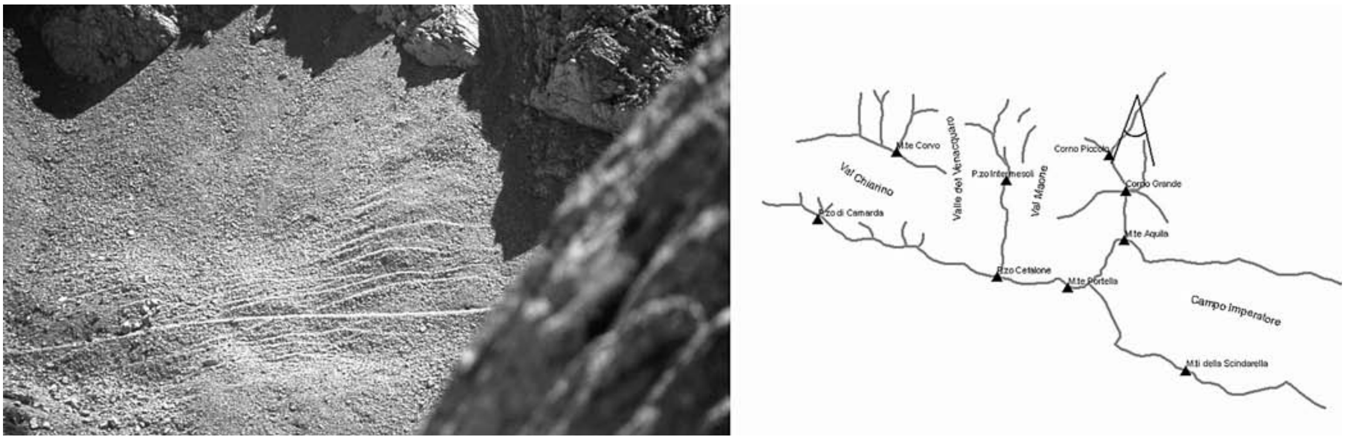


FIG. 6 - Surface with turf-banked lobes and debris prevalence near the Due Corni saddle.

Similarly, the presence of a small block stream (fig. 7) in the area of the Sambuco Trough seems to reflect the occurrence of seasonal ice. This is a small deposit (approximately 250 m long) made of frost wedged boulders and angular blocks transported and deposited by gelifluction and frost creep (IMONT & AIGEO, 2006) within a small

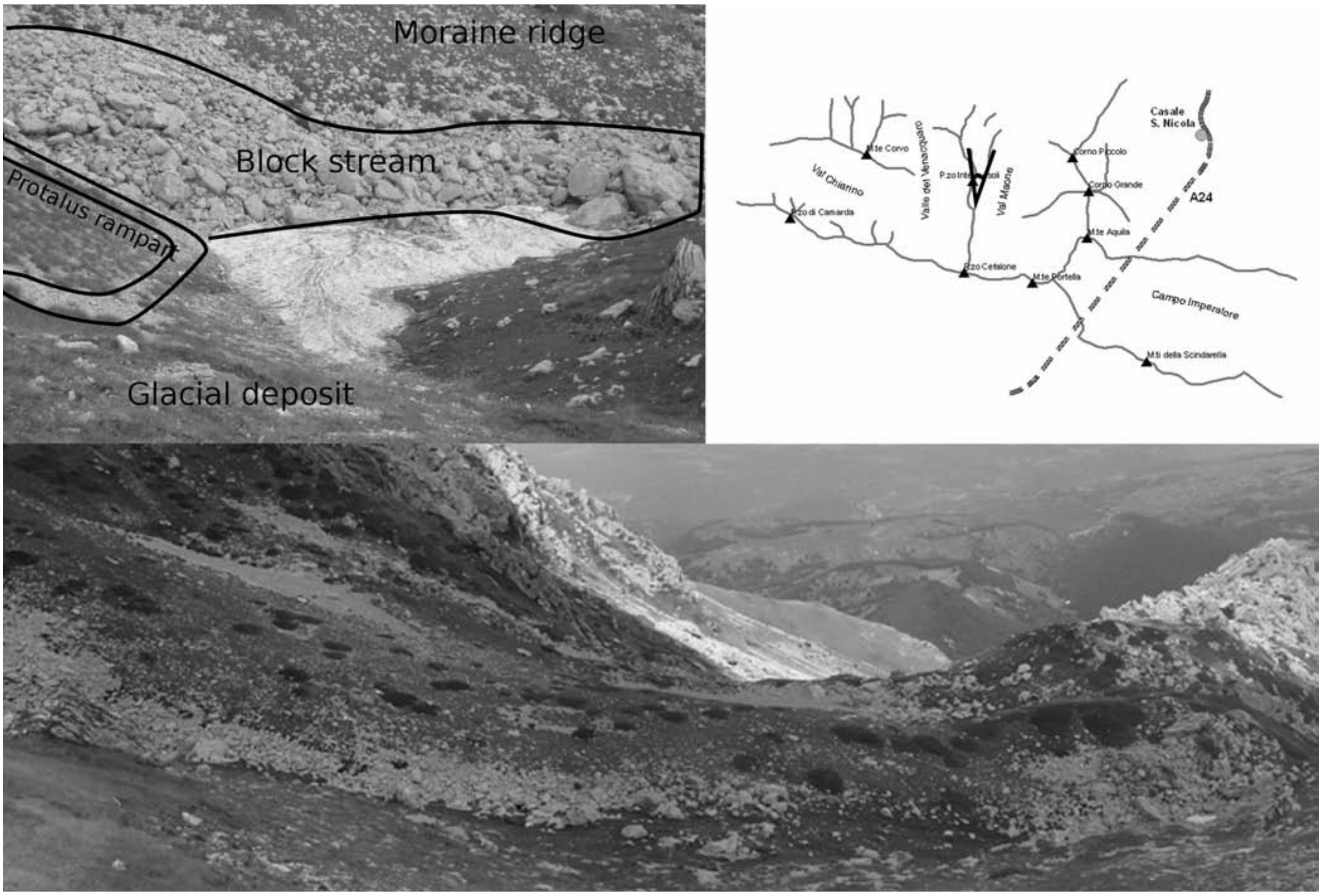


FIG. 7 - Particular of the small block stream surveyed in the Sambuco Trough area. When looking at the image from upstream in the valley, the deposits mentioned interact with each other, overlapping. In particular, the oldest and most downstream moraine ridge is covered by a block deposit that is very heterogeneous and attributable to a block stream. Upstream, the latter deposit is covered in part by debris deposits attributable to cryogenic processes linked to snow action. The block stream (photo below, in the foreground) presents a length of about 250 m and seems to be partially interrupted, towards the distal side, by an area characterised by more abundant fine elements and debris (highlighted by the presence of grass), possibly tied to leaching and gravitational deposits coming from the steep slope above and from the dismantling of the moraine ridge.

valley groove. The grains show an open work texture, with weaving linked to the removal of the fine particles in the superficial portions of the deposit by water drainage (Andersson, 1906; Smith, 1956; Potter & Moss, 1968), and they are deposed with the major axis roughly along the line of steepest gradient, except for those behind obstacles to flow. The freshness of the landform would presumably suggest an activity linked to the blocks creeping above ground ice; therefore, the presence of the block stream could also indicate the presence of permafrost (Harris, 1994), which in this particular case could be demonstrated with further investigations and quantitative measurements. Although this could be attributable to the presence of seasonal frost, it is more often reported in the literature (Van Steijn & *alii*, 2002; Boelhouwers, 2003) that the production of accumulations of blocks is not typical of cold climates but is instead the result of processes of azonal chemical-physical alterations (Guglielmin & *alii*, 2005).

The interaction of multiple, sometimes simultaneous processes (e.g., gravitational, cryogenic and running water-related) makes it difficult to attribute a landform to a single process; however, the authors attribute it to the geomorphological process considered to be dominant during the morphoclimatic conditions associated with its genesis. In fig. 7, the simultaneous action of multiple processes in the same area is highlighted, as is their temporal and spatial diachrony. In fact, it is apparent how the various mentioned deposits stratigraphically overlap, suggesting a transition, both in time and space, from a glacial environment (marked by moraine ridges and glacial deposits) to a cryogenic environment (highlighted by block streams and cryogenic deposits) and gravitational processes.

Among the cryogenic landforms, protalus ramparts should also be mentioned. The main active protalus rampart detected in the area is, as previously mentioned, at the base of the scree slope descending from the frontal moraine of the Calderone Glacier at an average elevation of approximately 2,500 m a.s.l. (fig. 8). Extending for approximately 250 m and with average thickness of less than 2 m, it is poorly colonised by vegetation (only on the downstream side) and is mainly fed by the action of avalanches.

Small active protalus ramparts were detected (clearly visible even in the aerial photos) in Val Maone, both on the true left and right, at the outlets of avalanche channels

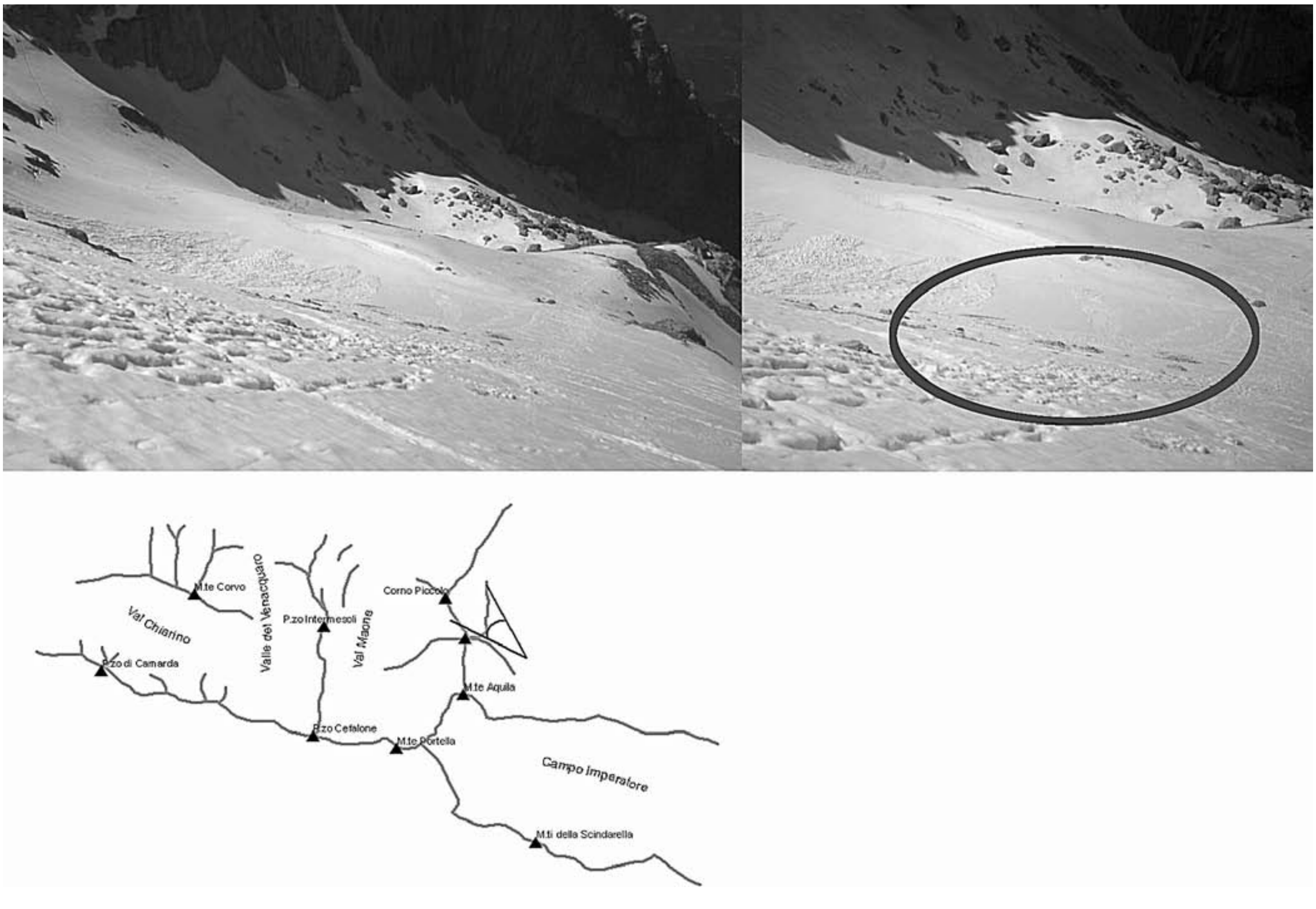


FIG. 8 - An especially active protalus rampart at the base of the frontal moraine of the Calderone Glacier. The impact of avalanches on the evolution of the landform is apparent in the right photo.

and tracks where there is a constant occurrence of full-depth slab avalanches. Another active protalus rampart was identified in conjunction with a snowfield located behind a rock wall (also characterised by the presence of a nivation hollow) near the «C. Franchetti» hut (fig. 9). After two years of ground temperature measurements (Pecci, 2009) in a study of the particular dynamic of this snowfield, the presence of permafrost activity in the area was highlighted, taking into account the definition of permafrost, *sensu* Guglielmin (2004).

The results of the instrumental measurements together with morphological evidence confirmed that its action has shaped the deposit. The presence of these landforms similar to festoons, lobes and ridges on the debris field creeping on a weak slope downstream of the snowfield and of the protalus rampart in discussion (fig. 9) are typical of an active rock glacier. All of this evidence in conjunction with the signal recorded from the underground temperature (Pecci, 2009) motivate the continuation of the research effort to study the implications of the presence of an active rock glacier (which is the only active rock glacier currently reported in the Gran Sasso d'Italia area) based on quantitative measures of ground temperature.

Obvious inactive protalus ramparts, fully colonised by vegetation, are present on the Maone valley slopes between the elevations of 1,780 and 1,920 m a.s.l. They border scree slopes descending from the crags of Primo Scrimone and from the pillars of Pizzo Intermesoli. The ridges of these protalus ramparts, some metres high, have in one case a hint of lobe, which would suggest a probable transition from an earlier rock glacier landform. The degree of colonisation of these inactive landforms and the degree of corrosion of the larger carbonate grain similar to that of nearby morainic ridges attributable to the Apennine II Stage (Giraudi & Frezzotti, 1995) would suggest an age similar to that of the ridges themselves.

Channels of avalanche tracks are present mainly in the Maone valley-Ginepri valley area. At the mouth of this latter, avalanche cones were detected; they are also highlighted by the presence of «fresh» grains interbedded in shrub vegetation residues and reworked by water action.

In other sectors of the same valley, characterised by regular detachment of seasonal full-depth slab avalanches (De Sisti & *alii*, 2004), the morphological action is highlighted by the bent down and hooked-base character of the timber, which consists of beech trees with small stems in the centimetre range and no large trees, which evidently do not possess the necessary flexibility to withstand the avalanches that detach from Corno Piccolo, in particular at about the elevation of 1,530 m, and rise up for several metres on the opposite side of the valley.

Given the importance of these phenomena for the purposes of risk prevention for the many climbers and ski-mountaineers frequenting the area during the winter, as well as their timely seasonal occurrence and large area of influence, it was considered appropriate to use the special linear symbol proposed by D'Alessandro & *alii*, 2003 on the areas affected by the passage of seasonal avalanches to indicate the location of these avalanches and to not mask the other symbols.

In the Gran Sasso d'Italia area many perennial snowfields survived in past years, some of which are cited in the literature. An inactive snowfield is located on the scree slope below the frontal moraine of the Calderone Glacier. It was used in the first part of last century with the glacier itself for ski racing events that took place in the month of June. Currently there is only a small permanent snowfield of modest thickness located at an elevation of 2,400 m a.s.l. near the «C. Franchetti» hut (fig. 9) in the Cornacchie valley. This snowfield survived the recent hot summer seasons (particularly those of 2002, 2003 and 2007) due to the protection of the vertical walls above it and to its northern aspect and to the generally low insolation; the Cornacchie valley is, in fact, almost completely enclosed by a fence of high peaks.

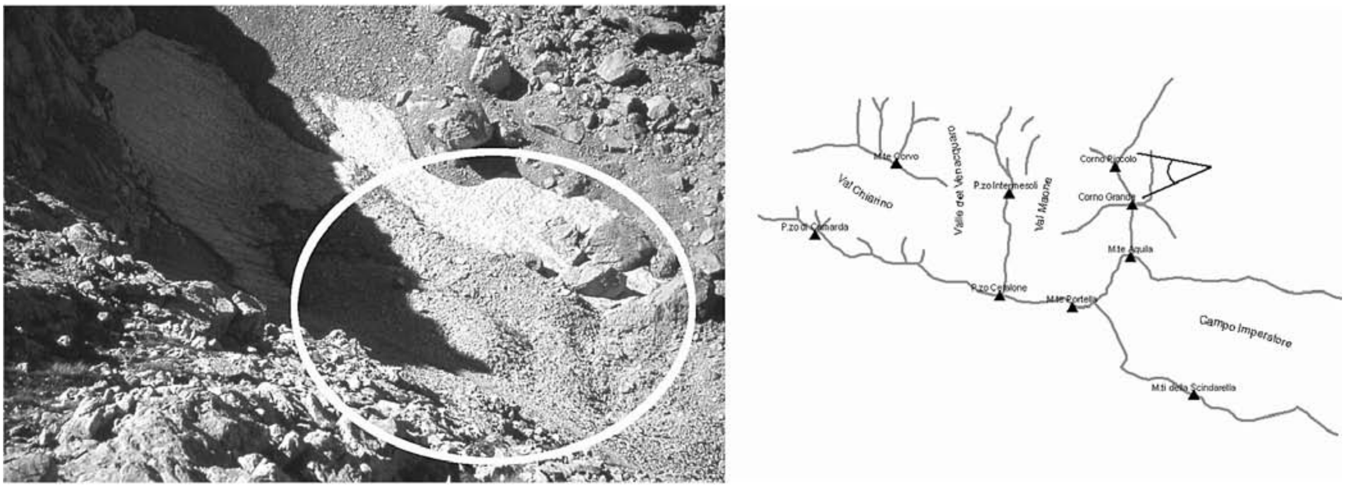


FIG. 9 - Detailed view of the protalus rampart in the proximity of the «C. Franchetti» hut (Cornacchie valley) and of the active rock glacier below.

ANTHROPOGENIC LANDFORMS

Given the elevation and the predominantly rugged features of this rocky area, human presence and activities are currently limited to tourism, skiing, hiking and climbing. Sheep farming is widely practiced at Prati di Tivo, in the meadows above Bosco S. Nicola and in the grassy crest area of Arapietra.

Tourism is concentrated in well-defined itineraries, and this is reflected in the conditions of the zones subject to more frequent passersby. The continuing passage along the most well-travelled trek in the Gran Sasso d'Italia massif, namely from Prati di Tivo to the «C. Franchetti» hut and to the summit of Corno Grande, led to the complete removal of the grassy cover in an area just upstream of «Madonnina» at 2,030-2,060 m a.s.l. (fig. 10). This consequently triggered erosion, that was stabilised only recently with «live» defences.

CONCLUSIONS

This geomorphological study and cartography highlight the geomorphological complexity of the summit area of the Gran Sasso d'Italia massif, and they show how many of the landforms are predominantly polygenic and are therefore not always attributable to a single process or to a predominant agent.

The area has strong relief energy linked to the particular arrangement of the major tectonic features that characterise it, with the major Tre Selle fault (Ghisetti & Vezzani, 1990) on the southern side, the numerous northward oriented thrusts (fig. 2) and the N-S lineament. Neotectonic evidence occurs in the south-western border of the range (Blumetti & Guerrieri, 2007) and spreads on recent Holocene deposits and on gravitational rock fall deposits in some cases reactivated during the earthquake of April 2009 (Falcucci & *alii*, 2009). Together with the tectonic activity, the action of Quaternary glaciers had a strong influence on the current morphology of the massif.

The Quaternary climatic fluctuations (which have important alternating periods of sub-aerial wasting and stages of debris production), together with energy relief and the particular arrangement of lineaments, have created ideal conditions for the production of the «raw material» needed to allow the glaciers to leave important characteristic deposits and landforms.

The uplift of the chain occurred in morphoclimatic conditions different from the Present ones, which therefore created widespread instability that led to tectonic building in a continual search for equilibrium. The many landslides in the area are attributable to this pattern and are favoured by post-glacial tensional release, especially within the glacial cirques.

The main output of the geomorphological survey consists of the geomorphological map that complements a survey previously published (D'Alessandro & *alii*, 2003), with special regard to the area between the Pizzo Intermesoli-Colle dell'Asino and the Pietracamela-Prati di Tivo sectors.

In this area, gravitational processes are predominant, manifest and in progress. Obvious signs of gravitational action are manifested in the numerous rock falls, in the degradation ridges and in the numerous scree slopes and talus cones. Further effects related to gravitational processes are the morphological evidence of DSGSD surveyed near the Corno Piccolo summit, the eastern peak of Corno

FIG. 10 - Human-caused erosion on the crest of Arapietra; in the right figure, note the attempts at natural stabilisation; in the figure on the left, a view from Corno Piccolo on the extent of the phenomenon.

Grande, the Arapietra crest and Colle dell'Asino. The result is the evolution of an area still searching for a new condition of stability, in which it is worth mentioning that the response of the territory to new conditions does not seem to be immediate, but occurs with differentiated response times. For example, whereas in the downstream areas an increase in gravitational processes happens at the expense of glacial processes, behind the cirques this transition becomes predominant or seems to fade in cryogenic/nivation and paraglacial (*sensu* Ballantyne, 2002) processes, which in the last decade are having increasingly typically paraglacial connotations, especially with respect to deposits and areas recently abandoned by ice (Pecci, 2009; Pecci, 2010).

In this framework, the snowfield found near the «C. Franchetti» hut is of particular interest; it appears to have survived through the hottest summers of 2002, 2003 and 2007, while the Calderone Glacier was in ablation, and also shows the presence of permafrost and of an active rock glacier. Equally interesting are the areas with surface turf-banked and debris lobes; these areas, most of which are found (between 1,600 and 1,800 m a.s.l.) in the Maone valley, are deemed to be related to the presence of seasonal ice.

Although these landforms survive and have survived thanks to the protection provided by the vertical walls above against caloric intake, to avalanche accumulation, to conditions of favourable exposure and generally low insolation levels in wintertime, they represent climate indicators worthy of attention and witnesses of spatial and temporal diachronic processes.

This kind of dynamic correlation between landforms and processes can lead to a better understanding of the delicate morphoclimatic equilibrium and, in addition, can enable more appropriate land management. In fact, it can be expected that the possibility of a morphological change process occurring in a given area is related to what has already occurred in adjacent areas or at different times.

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